The Experience with Emissions Control Policies in the United States

U.S. Environmental Protection Agency

Office of Atmospheric Programs

Staff Paper

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Acronyms

ARAC	Acid Rain Advisory Committee
BACT	Best available control technologies
BART	Best available retrofit technologies
Bcf	Billion cubic feet of natural gas
Btu	British thermal unit of heat input (1 Btu = 1,055 joules)
CAA	United States Clean Air Act
CAIR	Clean Air Interstate Rule
CAVR	Clean Air Visibility Rule
CO	Carbon monoxide
CO_2	Carbon dioxide
EPA	United States Environmental Protection Agency
ERC	Emission Reduction Credit
FGD	Flue Gas Desulfurization
KW	Kilowatt
KWh	Kilowatt hour
LAER	Lowest achievable emissions rate
m^3	Cubic meter
MW	Megawatt (1,000 kilowatts)
MWh	Megawatt hour (1,000 kilowatt hours)
NO_2	Nitrogen dioxide
NO_X	Nitrogen oxides
NOAA	United Status National Oceanic and Atmospheric Administration
NSPS	New Source Performance Standards
NSR	New Source Review
O_3	Ozone
OTAG	Ozone Transport Assessment Group
PM	Particulate matter
PSD	Prevention of Significant Deterioration
RACT	Reasonably available control technologies
SIP	State Implementation Plan
SO_2	Sulfur dioxide
US	United States
μeq	Micro-equivalent
μg	Micrograms
μm	Micron / micrometer

Notes

Unless otherwise noted, all measurements are in metric tons.

1. Background

The electric power sector plays a critical role in economic growth and quality of life in the United States (US) by providing safe, reliable electricity to industry, government, and residential consumers. The electric power sector, however, is also a major source of air pollution. To produce electricity, through the combustion of fossil fuels, such as coal, oil, and natural gas, electric power plants emit sulfur dioxide (SO_2), nitrogen oxides (NO_X), particulate matter, mercury, carbon dioxide (CO_2), and other pollutants. Research has shown that these emissions have a significant impact on human health, forests and farmland, wildlife, buildings and infrastructure, and cultural resources (e.g., statues and relics.) In response to these impacts, the US government has developed approaches to air quality management, including policies and programs to reduce emissions and mitigate environmental and human health impacts in their respective countries.

The US has also recognized the importance of energy efficiency to cost-effectively avoid emissions and conserve resources. Energy efficiency initiatives, including regulatory programs, educational programs, and voluntary efforts, have been implemented to improve the efficiency of power generation and transmission and to reduce consumers' demand for electricity. These efforts not only lower pollution from energy use, but also serve to increase the productivity of the economy.

This report explores selected US efforts to reduce emissions from a sector – the electric power sector – that is critical to the US's economy. While the primary focus of this report is the control and avoidance of SO_2 emissions in the power sector, the report also highlights selected efforts to control and avoid NO_X emissions for this industry. Furthermore, this report identifies some of the lessons learned in designing and implementing air quality policies and programs.

2. Environmental Challenge – Impacts to Human Health and the Environment

Concerns in the US over increasing emissions from the power sector have spurred efforts to identify, assess, and address the resulting environmental problems and impacts. At first, these efforts focused largely on problems related to direct particulate emissions (i.e., soot) and acid deposition. Additional scientific and health research, however, have revealed a need to examine other issues related to power sector emissions, including fine particulates, regional haze, ground-level ozone (O_3), nitrogen deposition (nutrient enrichment), mercury, and climate change. In general, direct particulate emissions from the electric power sector are largely under control in both countries. The environmental and health issues discussed in this section are currently of greatest concern in the US.[1]

Acid Deposition

Acid deposition—more commonly known as acid rain—occurs when SO_2 and NO_X emissions react with water, oxygen, and oxidants in the atmosphere. Once formed, these acidic compounds can be transported hundreds or thousands of kilometers, across provincial/state and national borders, where they impair air quality and ultimately

[1] Power sector emissions of SO_2 and NO_X (primary pollutants) can lead to harmful respiratory effects. Secondary pollutants (acid rain, fine particles, ozone) are formed in the atmosphere from direct SO_2 and NO_X emissions and other substances. These secondary pollutants have more substantial environmental and health impacts than direct SO_2 and NO_X emissions alone and, therefore, are the focus of this section.

fall from the atmosphere in either dry (gases, particles) or wet (rain, snow, fog) form. Both dry and wet acid deposition pose serious threats to aquatic and terrestrial ecosystems as well as building and cultural materials.

Acid deposition can change surface water chemistry, making lakes and streams more acidic and releasing toxic substances into the water. An ecosystem's ability to counteract acidification is known as its acid neutralizing capacity. Acidification of surface water and the surrounding soil, in conjunction with low acid neutralizing capacity, can be a harmful combination for sensitive fish populations, causing species loss (NAPAP, 1991). Furthermore, acidification can lead to the release of aluminum from soils into lakes and streams (NAPAP, 2005; Lawrence et al., 1995). Aluminum is highly toxic to many aquatic organisms and can result in further loss of fish and other species as well as decreases in fish size and population density (Van Sickle et al., 1996; Driscoll et al., 2001).

Many of the same processes that determine lake and stream acidity and ecological effects also govern acid rain's impacts on agriculture and forests. Acid deposition impacts terrestrial ecosystems, for example, by contributing to declining growth rates, foliage loss of nutrients, and mortality in forests. Acidification leaches important nutrients (particularly calcium) from the soil while the mobilization of aluminum caused by acidification can interfere with nutrient uptake by plant roots (NAPAP, 2005). Buffering capacity determines how farmlands and forests react to acid deposition, increasing pH, and the release of aluminum. Similar to lakes and streams, low buffering capacity inhibits the ability of soil to neutralize additional acidic compounds, further compounding the effects of acidification. This combination of factors causes some plant species to become more susceptible to stressors like disease, insects, drought and temperature extremes (DeHayes et al., 1999; Schaberg et al., 2001).

Automobile paints and finishes, outdoor structures such as bridges and buildings, and cultural monuments and historic buildings are all susceptible to the accelerated weathering process caused by acid deposition. Marble and limestone structures are particularly at risk. Bronze, stone and painted surfaces are also impacted (NAPAP, 2005). While both wet and dry deposition can damage material sources, dry deposition appears to cause the most damage (Charola, 2001).

Fine Particulates

Research has shown that while acid deposition does not directly cause health problems, high concentrations of the constituents that contribute to acid rain (SO_2 and NO_x) can have negative human health effects. Particulate matter (PM) is a complex mixture of extremely small particles and liquid droplets in the air and can be formed in two ways. "Primary" PM is directly emitted into the air from sources such as cars, trucks, heavy equipment, forest fires, some industrial processes, and burning waste. "Secondary" PM is formed in the atmosphere by transformations of gaseous emissions such as SO_X, NO_X, and volatile organic compounds (VOC). Examples of secondary particle formation include the conversion of SO_2 to sulfuric acid droplets that further react with gaseous ammonia to form various sulfate particles (e.g., ammonium sulfate or ammonium bisulfate), the conversion of nitrogen dioxide (NO_2) to nitric acid vapor that reacts further with ammonia to form ammonium nitrate particles, and reactions involving gaseous VOC that form secondary organic aerosol particles (EPA, 2004).

Atmospheric particles can be grouped according to their aerodynamic and physical sizes, including fine particles (< 2.5 μm) and coarse particles (>2.5 μm). In 2006, EPA released a Criteria Document and Staff Paper proposing to lower the National Ambient Air Quality Standard in the US for fine particles. These two documents, based on thousands of peer-reviewed scientific studies, are part of an extensive scientific assessment process that includes an extremely rigorous scientific peer review and public comment process. Specifically, these documents referenced several large-scale, multi-city and long-term epidemiological studies of the health effects of particulate matter.

Fine particles (PM2.5) pose the greatest concern since the particles are small enough to get deep into the lungs and bloodstream, causing serious health problems. Scientific evidence has established links between exposure to fine particle pollution and various cardiac and respiratory morbidity endpoints including non-fatal heart attacks; increased hospital admissions; emergency room visits and doctor's visits for respiratory diseases; increased hospital admission and emergency room visits for cardiovascular diseases; increased respiratory symptoms such as coughing, wheezing and shortness of breath; lung function changes, especially in children and people with lung diseases such as asthma; changes in heart rate variability; and irregular heartbeat (EPA, 2004).

Furthermore, a substantial body of published scientific literature documents the correlation between elevated PM concentrations and increased mortality rates (EPA, 2004). Researchers have found statistically significant associations between premature mortality and both short- and long-term exposure to PM. Cohort methods have been used to examine the potential relationship between community-level PM exposures over multiple years (i.e., long-term exposures) and community-level annual mortality. Cohort analyses are thought to better capture the full public health impact of exposure to air pollution over time, because they capture the effects of long-term exposures and possibly some component of short-term exposures (Kunzli et al., 2001; NRC, 2002). The most extensive long-term exposure studies are based on data from the Harvard "Six-Cities Study" (Dockery et al., 1993; Laden et al., 2006) and the "American Cancer Society Study" (Pope et al., 1995, 2002, 2004). These studies have found consistent relationships between fine particle indicators and premature mortality across multiple locations in the US. Furthermore, the Health Effects Institute (HEI), a scientific group supported jointly by government and industry, conducted independent and detailed reviews of numerous studies linking PM and premature mortality. HEI validated the data and methods used in these studies and supports their conclusions regarding a link between PM and premature mortality.

Regional Haze

Haze is caused when sunlight encounters very small pollution particles in the air (Malm, 1999). Light is either absorbed by these particles or scattered away, reducing clarity and color and affecting an observer's ability to see long distances clearly. Some haze-causing pollutants (mostly fine particles) are directly emitted to the atmosphere by a number of activities such as electric power generation, various industrial and manufacturing processes, truck and auto emissions, burning related to forestry and agriculture, and construction activities. Other haze-causing pollutants (such as sulfates and nitrates) are formed when gases emitted to the air form particles as they are carried downwind. Because emissions from the activities mentioned above generally span broad geographic areas and can be transported great distances, haze and visibility issues generally occur regionally. Higher levels of pollutants in the air cause more absorption and scattering of light, decreasing visibility. Certain particles, such as sulfates, scatter more light, particularly during humid conditions (Malm, 1999).

Reduced visibility negatively affects people's enjoyment of daily activities and recreation, including the enjoyment of national parks and scenic vistas. To provide some context for the regional haze problem, typical visual range in most of the Western US is

97 to 145 kilometers, or about one-half what it would be without haze-causing air pollution. In most of the US, the typical visual range is 24 to 48 kilometers, or about one-third of the visual range under natural conditions (EPA, 2006b).

Nitrogen Deposition (Nutrient Enrichment)

In addition to contributing to the formation of acid deposition, NO_X emissions play a role in nutrient enrichment of coastal estuaries, lakes, and streams. Nitrogen deposition (nitrate and ammonium) can accumulate in soil and leach into streams and lakes when more nitrogen is deposited than plants can use (Aber et al., 1989). This causes nitrogen saturation of watersheds and can often lead to ecosystem imbalances and species diversity shifts.

Elevated levels of nitrogen in soils can lead to a surplus of nutrients, resulting in over-fertilization. This can change the mix of plant species in an area and lower species diversity by favoring some nitrogen-tolerant species over other species that are more sensitive (Inouye and Tilman, 1988).

Excess deposition of nitrate and ammonium to aquatic systems can cause eutrophication (Howarth et al., 2000; Valigura et al., 2001). Eutrophication is the accelerated growth of algae (blooms), triggered by the addition of excess nitrogen to coastal estuaries, lakes, and streams. These algae blooms are detrimental to aquatic life after the algae die because their decomposition depletes the amount of dissolved oxygen in the water, leading to a condition known as hypoxia. Hypoxic zones can be lethal to fish and other aquatic life, causing widespread fish kills and dead zones (Burkholder et al., 1999). Furthermore, nutrient pollution contributes to *pfiesteria* outbreaks which cause rapid fish kills and are associated with health effects in humans (Morris, 2001).

Ground-Level Ozone

Ozone in the Earth's upper atmosphere (the stratosphere) shields the planet from the sun's harmful ultraviolet rays. At ground level (the troposphere), ozone can be harmful to human health and ecosystems. Ozone pollution forms when emissions of NO_X and VOCs react in the presence of sunlight. Ozone itself is rarely emitted directly into the air. In the US, major sources of NO_X and VOC emissions include motor vehicles, industrial facilities, and electric power plants (EPA, 2007d).

Meteorology plays a significant role in ozone formation. Dry, hot sunny days are most favorable for ozone production. In general, ozone concentrations increase during the daylight hours, peak in the afternoon when the temperature and sunlight intensity are highest, and drop in the evening. Because ground-level ozone concentrations are highest when sunlight is most intense, the warm summer months (May 1 to September 30) are known as the "ozone season." Weather also affects ozone concentrations and how quickly ozone is transported or disperses from an area.

At levels found in many urban areas, ozone can aggravate respiratory diseases such as asthma, emphysema, and bronchitis, and can reduce the respiratory system's ability to fight off bacterial infections (EPA, 2007e). Exposure to ozone is associated with increases in hospital admissions and emergency room care, while long-term, repeated exposure to ozone can cause permanent damage to the lungs. While the body of research addressing ozone impacts to respiratory system health is substantial, studies of cardiovascular system effects of ozone exposure are less certain. Finally, breathing ozone may contribute to premature death in people with heart and lung disease. (EPA, 2007e)

In addition to negatively affecting human health, ground-level ozone can also damage vegetation and ecosystems, leading to reduced agricultural crop and commercial forest yields and increased plant susceptibility to diseases, pests, and other stresses (e.g., harsh weather) (EPA, 2007e). Ozone, absorbed through leaves, damages foliage and negatively affects a plant's ability to create energy through photosynthesis. This effect impacts the health of the entire plant, including its ability to sustain a healthy root system. The outcomes of ozone exposure include foliar injury and premature aging. These outcomes adversely affect the health of forests; the market value of crops and plants; and the landscape of cities and national parks, forests, and recreation areas. (EPA, 2007e).

Mercury

Mercury is a persistent, bioaccumulative and toxic pollutant pervasive in the environment. Although it is a naturally occurring chemical element, anthropogenic (human-caused) emissions account for about two-thirds of mercury globally (Pacyna and Pacyna, 2006). While there are some uncertainties regarding mercury emission inventories, the United Nations Environment Programme estimates that globally, the largest mercury emitting source category is the combustion of fossil fuels, particularly coal-fired power and heat production (UNEP, 2003).

Mercury is emitted into the atmosphere in three forms: elemental mercury (Hg^0), reactive gaseous mercury (RGM), and fine particulate mercury (Hg(p)). Most of the mercury in the atmosphere (≈98 percent) is found in the elemental form, which is more inert and can be transported globally. In contrast, RGM and Hg(p) represent a small percentage of mercury in the atmosphere, but are more reactive and travel much shorter distances before depositing (Lindberg et al., 2007; Mergler et al., 2007). Mercury deposits to the Earth in wet and dry forms and can be a significant input to aquatic and terrestrial ecosystems.

Once mercury hits the landscape it can enter lakes, rivers and estuaries where it can transform into methylmercury, an extremely toxic form of mercury, and bioaccumulate in the aquatic food chain. Humans are exposed to mercury primarily by eating methylmercury-contaminated fish. Because the developing fetus is the most sensitive human group at risk to the toxic effects of mercury, women of childbearing age are regarded as the population of greatest concern. Children who are exposed to mercury before birth may be at increased risk of poor performance on neurobehavioral tasks, such as those measuring attention, fine motor function, language skills, visual-spatial abilities and verbal memory (NAS, 2000). Additionally, some research shows a link between exposure to mercury and cardiovascular disease in adult men (Salonen et al., 2000; Gaullar et al., 2002).

In addition to the health effects of mercury, there are environmental impacts as well. Mercury is mainly associated with negative impacts to wildlife, particularly fish-eating birds, and fish. Elevated levels of mercury in wildlife and fish have been associated with reduced offspring survival, decreased spawning and reproductive success, as well as impacts on mobility and general health (Evers, 2005; Chan et al., 2003).

Climate Change

For the past 200 years, the burning of fossil fuels, such as coal and oil, and deforestation has caused the concentrations of greenhouse gases to increase significantly in the atmosphere. For example, according to the US National Oceanic and Atmospheric Administration's (NOAA) Earth Systems Research Laboratory, carbon dioxide (CO_2) concentrations in the atmosphere increased from approximately 280 parts per million (ppm) in pre-industrial times to 382 ppm in 2006, a 36 percent increase. Methane concentrations also increased sharply during most of the 20th century and are now 148 percent above pre-industrial levels. Human activities have also resulted in growing atmospheric concentrations of nitrous oxide, tropospheric ozone and a range of fluorinated compounds (that are entirely anthropogenic). All of these greenhouse gases absorb and emit heat and thus tend to have a warming effect in the lower atmosphere.

According to data from NOAA and the US National Aeronautics and Space Administration, the Earth's average surface temperature has increased by about 1.2 to 1.4ºF in the last 100 years. Around the world, eleven of the last twelve years rank among the 12 warmest years on record (since 1850), with the warmest two years being 1998 and 2005. According to the Intergovernmental Panel on Climate Change (IPCC), which conducts periodic expert assessments, most of the warming in recent decades is very likely the result of human activities (IPCC, 2007a). Other climatic aspects, such as precipitation and storminess, are being affected. Finally, changes consistent with warming are also occurring in physical and biological systems (IPCC, 2007b).

Global temperatures are expected to continue to rise as human activities add CO_2, methane, nitrous oxide, and other greenhouse gases to the atmosphere. Climate models predict that the average temperature at the Earth's surface could increase from 3.2 to 7.2ºF above 1990 levels by the end of the last century (IPCC, 2007a). Most of the US is expected to experience an increase in average temperature greater than the global average. Precipitation changes, on the other hand, are more difficult to predict. Whether or not rainfall will increase or decrease remains difficult to project for specific regions, although precipitation is projected to increase on average globally.

Other climate change impacts include sea level rise and effects on forests, crop yields, and water supplies. Climate change could also affect human health, animals, and many types of ecosystems. The extent of these effects, and whether these effects prove harmful or beneficial, will vary by region, over time, and with the ability of different societal and environmental systems to adapt to or cope with the change.

3. US Electric Power Sector

Electricity production in the US is a vital activity that underpins the economy. The sector is critical to homes and businesses, and the reliable and relatively low-cost flow of electricity in the country has provided enormous economic benefit. Today, the power industry operates over 16,800 units nationwide and exhibits revenues of $298 billion annually (EIA, 2006b). The industry continues to make significant investments in new electric supplies and technologies in response to the needs of the US economy in the 21st century.

This section provides background on the power sector and discusses important aspects affecting electricity generation in the US. The functions of the US power sector can be separated into three distinct operating activities: generation, transmission, and distribution.

Generation

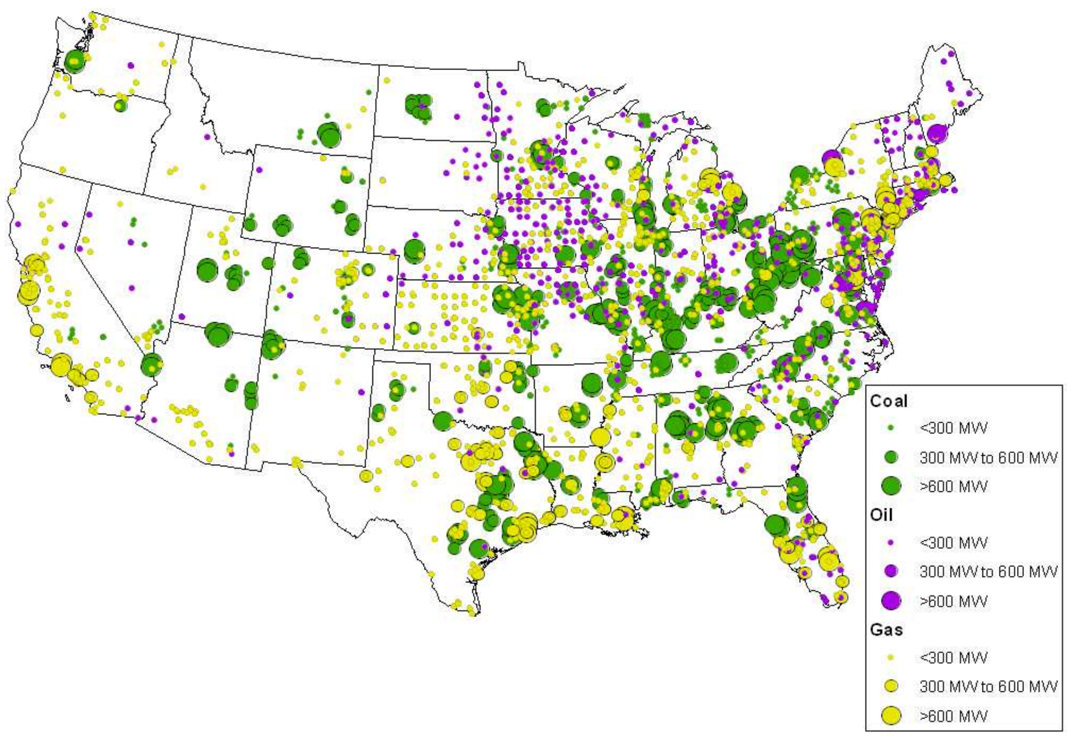
Electricity generation is the first process in the delivery of electricity to consumers. The process of generating electricity, in most cases, involves creating heat to power turbines which, in turn, power generators to create electricity. The US power sector is comprised of nearly 17,000 generating units, consisting of fossil-fuel fired units, nuclear units, and hydroelectric and renewable sources (see Table 3.1) dispersed throughout the country (see Figure 3.1). Together, these units generated 4,055 million MWh in 2005.

Table 3.1: Existing Capacity (Megawatts) by Energy Source[2], 2005

Energy Source	Number of Generators	Generator Nameplate Capacity
Coal	1,522	335,892
Petroleum	3,753	64,845
Natural Gas	5,467	436,991
Other Gases	102	2,293
Nuclear	104	105,585
Hydroelectric Conventional	3,993	77,354
Other Renewables	1,671	23,553
Pumped Storage	150	19,569
Other	45	928
Total	**16,807**	**1,067,010**

Source: EIA, 2006b.

Figure 3.1: Map of Fossil-fired Electric Generating Units, by Generation Capacity

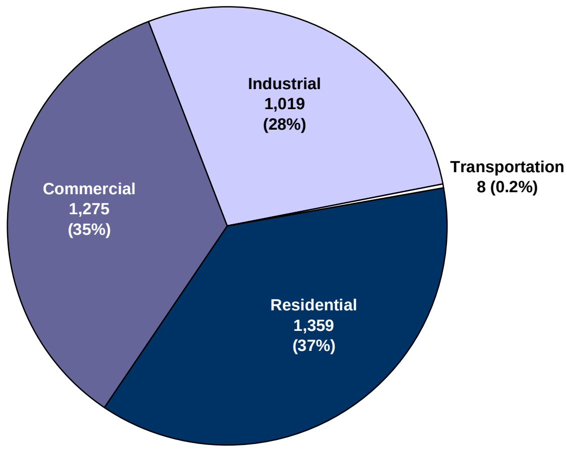


Source: EPA, 2006c

2 Capacity by energy source is based on the capacity associated with the energy source reported as the most predominant (primary) one, where more than one energy source is associated with a generator. Totals may not equal sum of components because of independent rounding.

These electric-generating sources provide electricity for commercial, industrial, and residential uses, each of which consumes roughly one-third of the total electricity produced (see Figure 3.2).

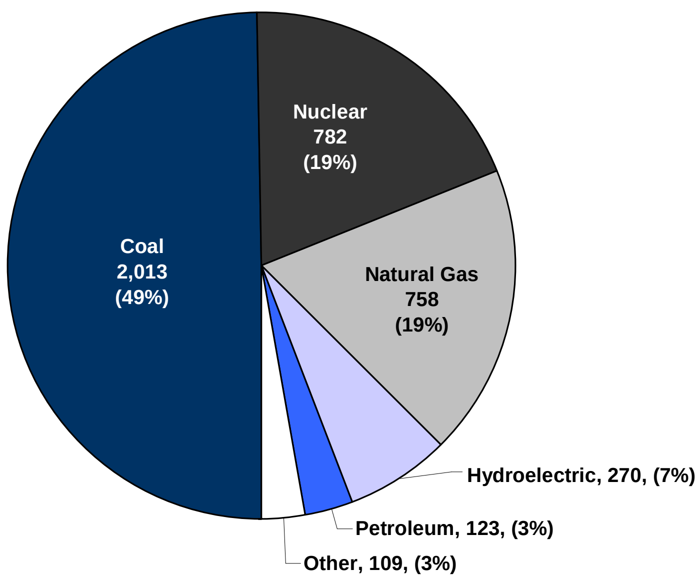
Figure 3.2: Total US Electric Power Industry Retail Sales by Sector, in Billion kWh, 2005



Source: EIA, 2006b

In 2005, electric-generating sources produced 3,661 billion kWh[3] to meet US electricity demand. Roughly 3/4 of this electricity was produced through the combustion of fossil fuels, primarily coal and natural gas (see Figure 3.3). Coal is an abundant resource in the US; one quarter of the world's coal reserves are found within the US, and the energy content of the nation's coal resources exceeds that of all the world's known recoverable oil (DOE, 2007). As such, coal combustion accounts for approximately half of all US electric generation.

Figure 3.3: Electricity Net Generation by Source, in Billion kWh, 2005[3]



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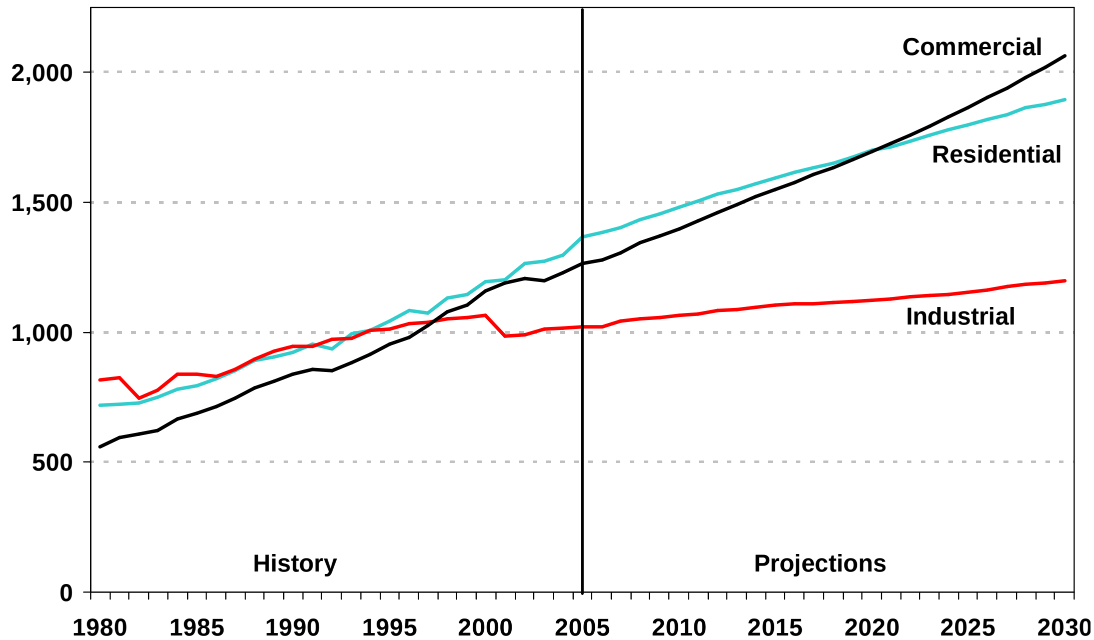
3 Retail sales and net generation may not correspond exactly because net generation data may include net exported electricity and loss of electricity.

Source: EIA, 2006b

Coal-fired generating units typically supply “base-load” electricity, which means these units operate continuously throughout the day. Coal-fired generation, along with nuclear generation, supplies the relatively constant portion of demand. Gas-fired generation, however, typically supplies “peak” power, necessary when there is increased demand for electricity. For example, “peak” power may be used during the day when businesses operate or when people return home from work and run appliances and heating/air-conditioning, as opposed to late at night or very early morning when demand for electricity is lower.

As electricity demand growth is projected to continue through 2030 (see Figure 3.4), it is likely that reliance on fossil fuels in the US will similarly grow over the next 10 to 20 years, even with aggressive development and deployment of new renewable and nuclear technologies (EIA, 2006b).

Figure 3.4: Historic and Projected Electricity Demand (Sales) by Sector, 1980-2030 (billion kWh)

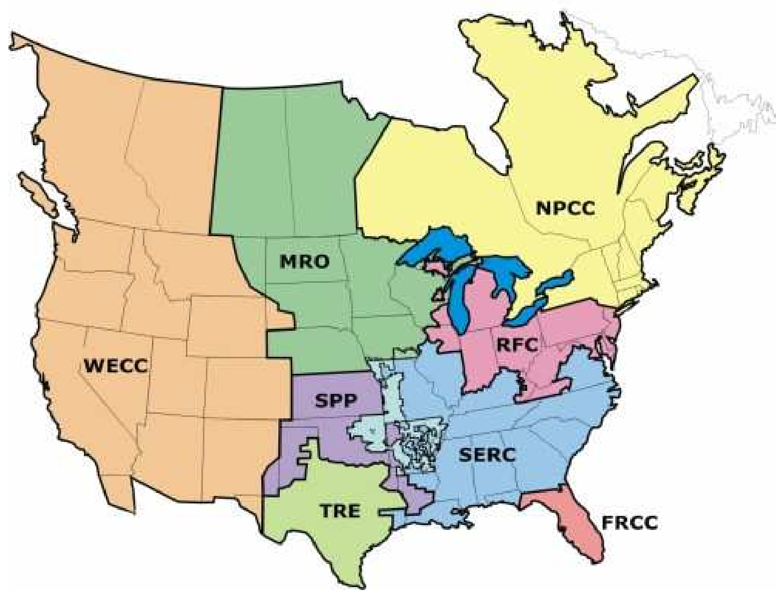


Source: EIA, 2007a

Transmission

Transmission is the term used to describe the movement of electricity, through the use of high voltage lines, from electric generators to substations where power is stepped down for local distribution. Transmission systems have been traditionally characterized as a collection of independently operated networks or grids interconnected by bulk transmission interfaces. In the US and Canada, the electricity system includes eight regional grids (see Figure 3.5).

Figure 3.5: North American Electric Reliability Corporation (NERC) Regions



Source: NERC, 2007

Within a well-defined service territory, the regulated utility has historically had responsibility for all aspects of developing, maintaining, and operating transmission of electricity. These responsibilities typically included system planning and expanding, maintaining power quality and stability, and responding to failures.

Distribution

Distribution of electricity involves networks of smaller wires and substations that take the higher voltage from the transmission system and step it down to lower levels that match the needs of customers. The transmission and distribution system is the classic example of a natural monopoly because it is not practical to have more than one set of lines running from the electricity-generating sources to neighborhoods or from the curb to the house.

Transmission and distribution have been considered differently than generation in current efforts to restructure the industry. Transmission has generally been developed by the larger vertically integrated utilities that typically operate generation and distribution networks. Distribution is handled by a large number of utilities that often only sell electricity. Electricity restructuring has focused primarily on converting the industry to fully compete the sale of electricity production or generation and not the transmission or distribution of electricity. In many state efforts, the restructuring of the industry is, in large part, the separation of generation assets from the transmission and distribution assets into separate economic entities. Transmission and distribution remain price-regulated throughout the country based on the cost of service.

Once distributed, electricity is consumed by the nearly 140 million consumers of the US electric power sector. Depending upon location and type of consumer, these consumers pay varying rates for power. See Table 3.2 and Figures 3.6 – 3.8 for more detailed information on both electricity generation and consumption.

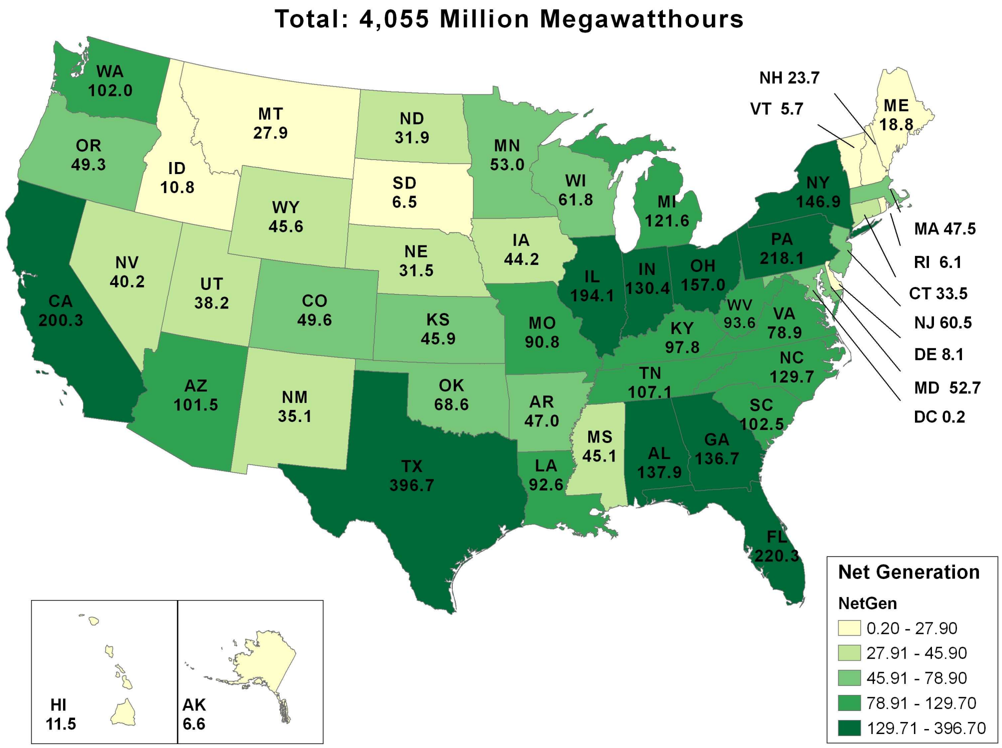
Table 3.2: Basic Electricity Statistics, 2005

Generation	
US Production (Net Generation)	4,054,688 million kWh (see Figure 3.6 for state-level detail)
US Electric Utility Production (Net Generation)	2,554,050 million kWh
Number of Electric Utility Generators	16,807
Largest Utility Plant by Net Generation	25,807,446 MWh (Palo Verde (Nuclear))
Electric Generators Fossil-Fuel Costs	
Coal	154 cents per million Btu (27.42 $/short ton)
Petroleum	644 cents per million Btu (26.56 $/barrel)
Natural Gas	821 cents per million Btu
Capacity	
Electric Generating Capacity (Net Summer)	(see Figure 3.7 for state-level detail)
Total	978,020 MW
Utility	562,420 MW
Non-Utility	415,980 MW
Largest Utility Plant by Capacity	7,079 MW (Grand Coulee (Hydro))
Consumption & Price	
US Consumption (Retail Sales)	3,660,969 million kWh
Largest Utility by Retail Sales	101,979,583 thousand kWh (Florida Power & Light Company)
Retail Prices of Electricity to Ultimate Customers	(see Figure 3.8 for state-level detail)
Residential	9.45 cents per kWh
Commercial	8.67 cents per kWh
Industrial	5.73 cents per kWh
Transportation	8.57 cents per kWh
US Total Average Price	8.14 cents per kWh
Number of Customers	
Total	138,367,159
Residential	120,760,839
Commercial	16,871,940
Industrial	733,862
Transportation	518
Largest Utility by Number of Customers	4,999,483 (Pacific Gas & Electric Company)
Average Residential Monthly Use	938 kWh
Average Residential Monthly Bill	$88.60

Largest Utility by Revenue	$9,445,101,000 (Southern California Edison Co.)
State Electricity Price Rankings	Highest - Hawaii 18.33 cents/kWh Lowest – Kentucky 5.01 cents/kwh

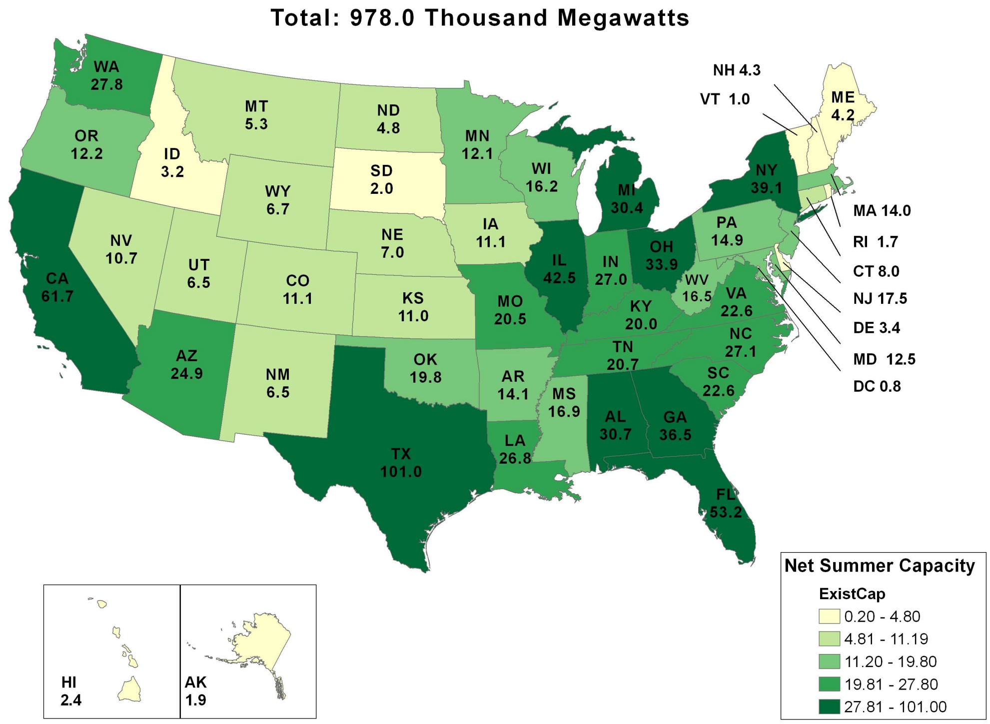
Source: EIA, 2007b

Figure 3.6: US Electric Industry Net Generation by State, 2005



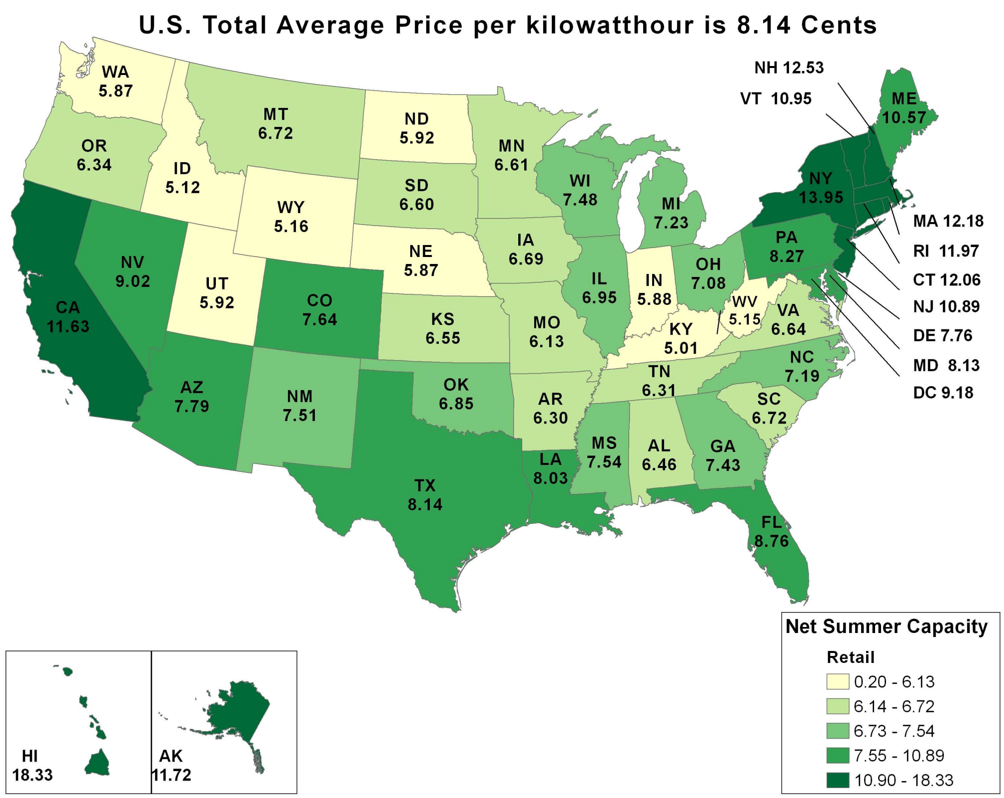
Source: EIA, 2006b

Figure 3.7: US Electric Industry Existing Capacity by State, 2005



Source: EIA, 2006b

Figure 3.8: Average Retail Price of Electricity by State, 2005



Source: EIA, 2006b

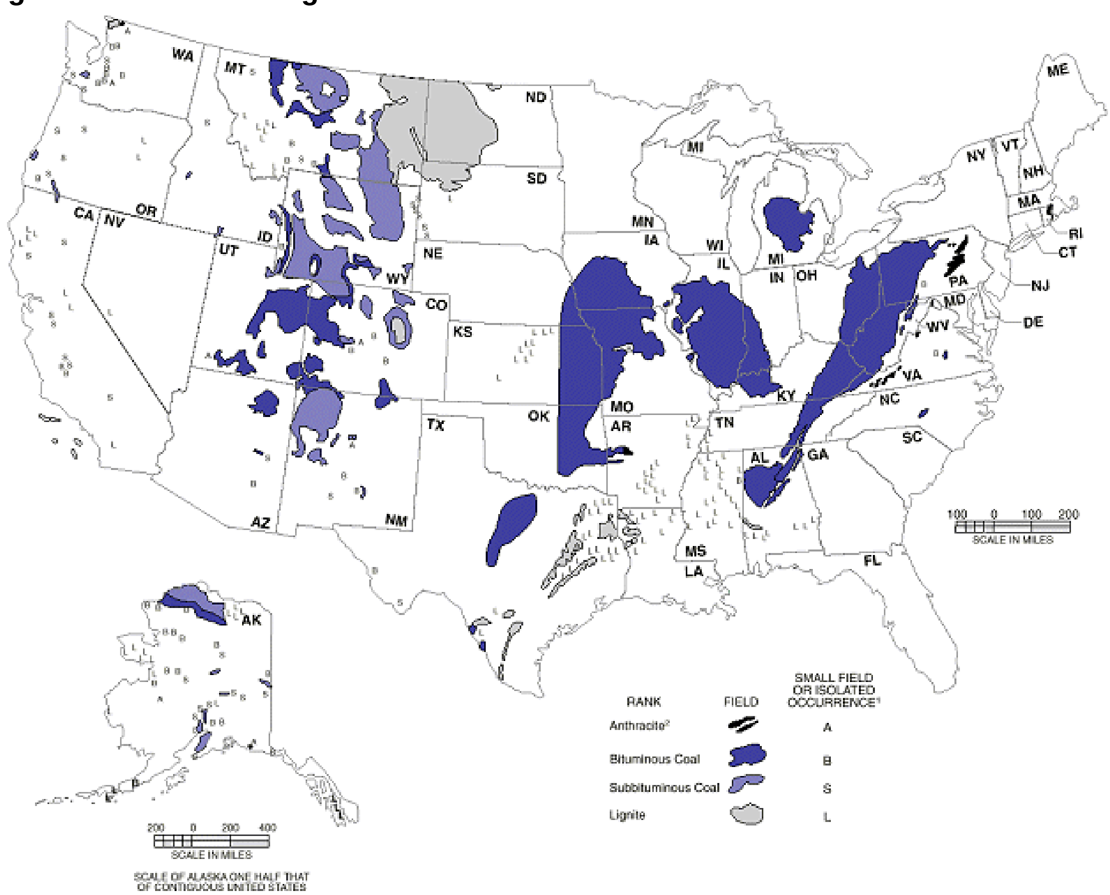
Fossil Resources

The electric generating sector is fueled primarily by the vast supply of domestic fossil resources. Coal is the most abundant fossil resource in the US, followed by natural gas and oil. These resources are distributed naturally throughout the country and distributed to power plants via an intricate transportation network.

Coal

The US has vast deposits of coal, more than any other fossil fuel. Recoverable coal reserves in 2005 stood at almost 18 billion short tons, almost half of which was located in Wyoming's Powder River Basin. Other states with significant reserves include Kentucky, Montana, North Dakota, and West Virginia. There are four major ranks of coal in the US classification scheme. These ranks, from highest heating value to lowest, include anthracite, bituminous, subbituminous, and lignite. Of the four ranks, bituminous coal accounts for over half (53 percent) of reserves. Bituminous coal is concentrated primarily east of the Mississippi River, with the greatest amounts in Illinois, Kentucky, and West Virginia. All subbituminous coal (37 percent of total coal reserves) is west of the Mississippi River, with most of it found in Montana and Wyoming. Lignite, the lowest-rank coal, accounts for about 9 percent of reserves and is found mostly in Montana, Texas, and North Dakota. Anthracite, the highest-rank coal, makes up only 1.5 percent of reserves and is concentrated almost entirely in northeastern Pennsylvania (see Figure 3.9).

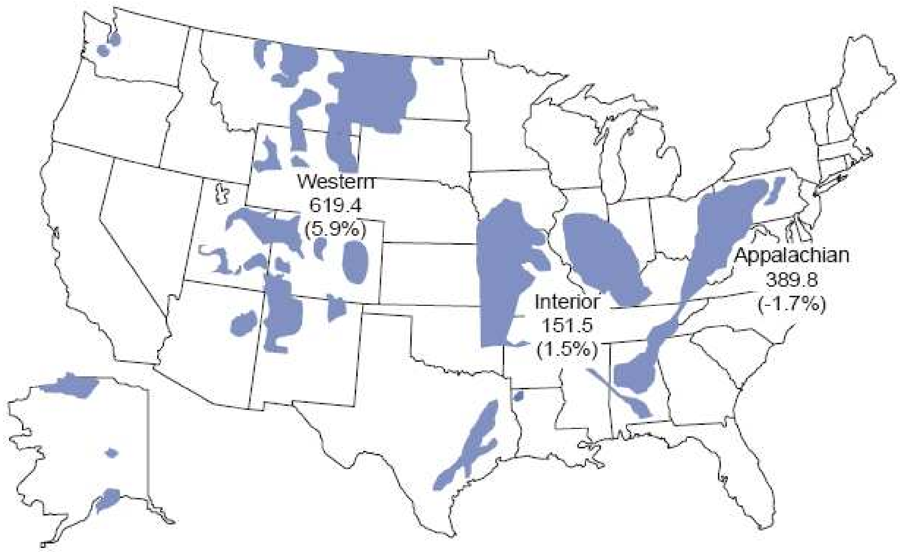
Figure 3.9: Coal Bearing Areas of the United States



Source: EIA, 1997

Total US coal production increased from 2005 to 2006 by 2.6 percent to reach a record level of nearly 1.2 billion short tons (EIA, 2007g). This increase occurred only in the Western and Interior regions; coal production in the Appalachian region decreased in 2006 to nearly 2004 levels (see Figure 3.10).

Figure 3.10: Coal Production by Coal-Producing Region, Million Short Tons in 2006, (Percent Change from 2005)[4]



Source: EIA, 2007g

In recent years, about 90 percent of coal production in the US has been consumed at domestic electric power plants. A variety of industries also use coal's heat and by-products to make plastics, tar, synthetic fibers, fertilizers, and medicines. The concrete, paper, and steel industries also burn large amounts of coal. In addition, a small amount of domestic coal is exported, mostly to Canada, Brazil, the Netherlands, and Italy. More than half of coal exports are used for making steel.

Coal use in the US has grown largely because of secure, abundant domestic reserves, relatively low prices, and a fairly extensive rail transportation system. Demand has been maintained through increasing mine productivity, which in turn has been supported by the operation of increasingly larger mines, more efficient mining machinery, advances in technology and control systems, and fewer mine personnel (EIA, 2006a).

Natural Gas

As of December 31, 2005, estimated proved reserves of dry natural gas in the US were 204,385 billion cubic feet (Bcf). Dry natural gas is the gas that remains after the economically liquefiable hydrocarbon portion has been removed from the produced gas stream at a natural gas processing plant. In addition to proved natural gas reserves, there are large volumes of natural gas classified as undiscovered recoverable resources. Those resources are expected to exist because the geologic settings are favorable. Over half of all onshore undiscovered gas resources are located in the Alaska and Gulf Coast regions. Over one-third of all undiscovered gas resources are estimated to be in Federal offshore areas, primarily near Alaska, in the Gulf of Mexico, and along the Atlantic Coast (EIA, 2007d) (see Figure 3.11).

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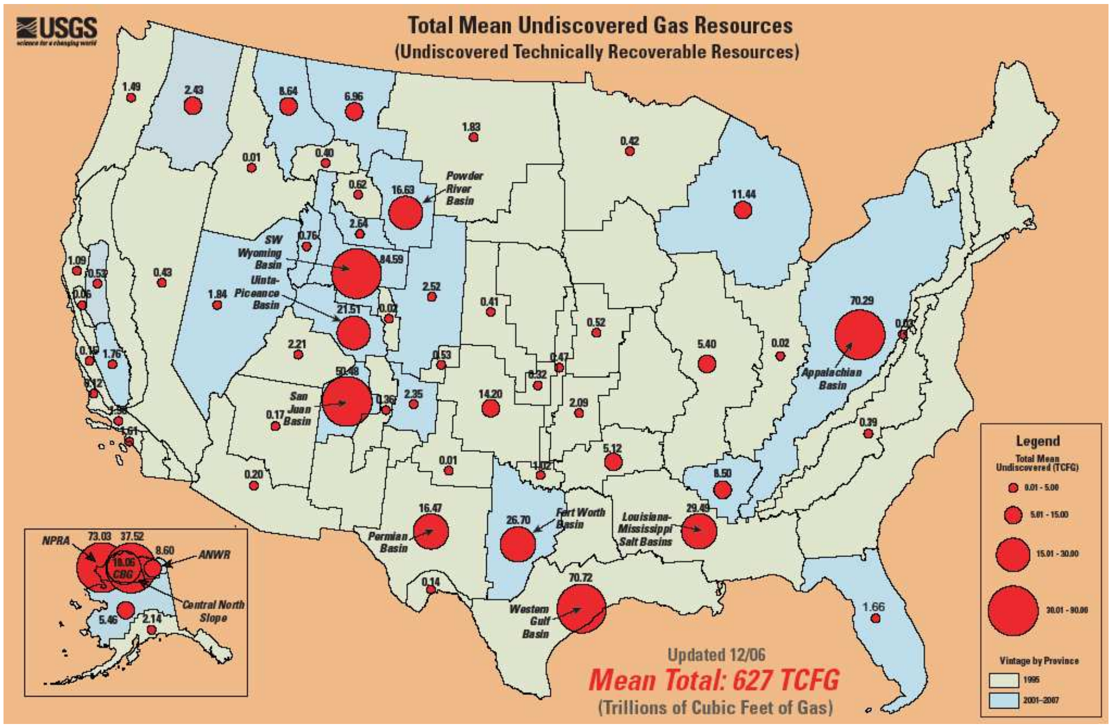
4 Note: Regional Totals do not include refuse recovery. US Total: 1,161.4 Million Short Tons (2.6 percent).

Figure 3.11: Total Mean Undiscovered Gas Resources[5]



Source: USGS, 2006b

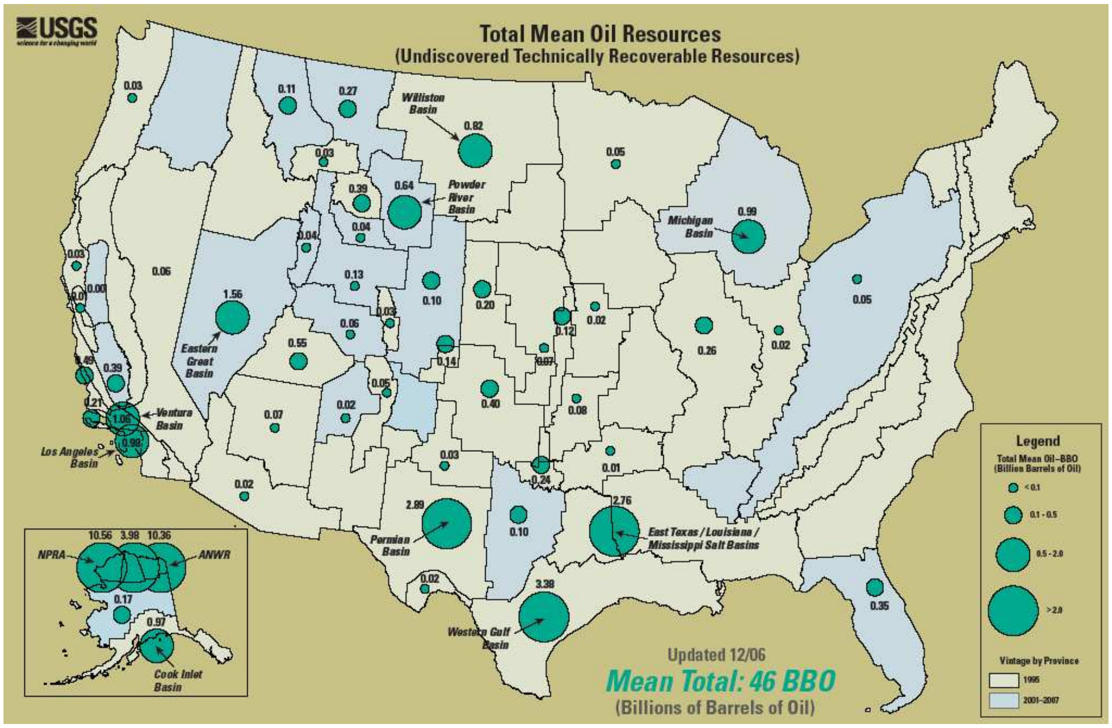
In 2005, US natural gas consumption reached 22,200 Bcf. The historical peak in US natural gas consumption occurred in 2000 when 23,300 Bcf were consumed. 1.7 Tcf was consumed by lease fuel, plant fuel, and pipeline and distribution use and thus not delivered to consumers. Of the volume delivered to consumers, residential natural gas consumption in 2005 was 4,800 Bcf, commercial consumption was 3,100 Bcf, and industrial consumption was 6,700 Bcf. The electric power sector consumed 5,900 Bcf of natural gas in 2005, accounting for just over 25 percent of consumption (EIA, 2007c). The US imports a relatively small amount of natural gas, primarily from Canada.

Oil

Total proved reserves of crude oil in the US, as of year-end 2005, are 21.75 billion barrels, a 1.8 percent increase from those of 2004. Thirty-one States have crude oil reserves. The top five are Texas, with 4.9 billion barrels; Alaska, with 4.2 billion barrels; California, with 3.4 billion barrels; Wyoming, with 704 million barrels; and New Mexico, with 690 million barrels. Also, substantial crude oil reserves exist in Federal Offshore fields: 4.0 billion barrels in the Gulf of Mexico and 441 million barrels in the Pacific (see Figure 3.12).

5 These resources are “undiscovered” and differ from the “proved reserves” cited above.

Figure 3.12: Total Mean Oil Resources[6]



Source: USGS, 2006a

Petroleum products, especially motor gasoline, distillate (diesel) fuel, and jet fuel, provide virtually all of the energy consumed in the transportation sector. Transportation is the greatest single use of petroleum, accounting for over 67 percent of all US petroleum consumed in 2005. The industrial sector is the second largest petroleum consuming sector and accounts for about 24 percent of all petroleum consumption in the US. Residential/commercial and the electric utility sectors account for the remaining 9 percent of petroleum consumption. Demand for petroleum products in the US averaged 20.8 million barrels per day in 2005. This represents about 3 gallons of petroleum each day for every person in the country. By comparison, petroleum demand averaged about 2 gallons per person per day in the early 1950's and nearly 3.6 gallons per person per day in 1978 (EIA, 2007f).

Deregulation and Restructuring

The ongoing process of deregulation of wholesale and retail electric markets is changing the structure of the electric power industry. In addition to reorganizing asset management between companies, deregulation is aimed at the functional unbundling of generation, transmission, distribution, and ancillary services the power sector has historically provided to a competitive market in the generation segment of the industry.

Beginning in the 1970s, government policy shifted against traditional regulatory approaches and in favor of deregulation for many important industries, including transportation, communications, and energy. These industries were all thought to be natural monopolies (prior to 1970) that warranted governmental control of pricing. Some of the primary drivers for deregulation of electric power included the desire for more

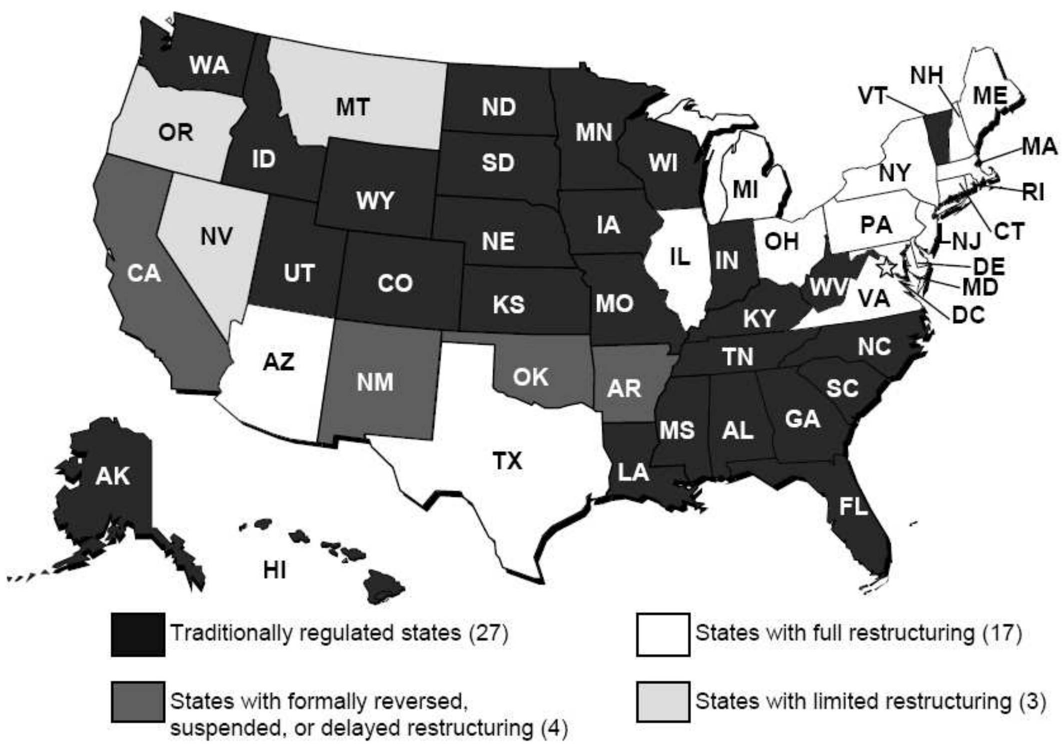
6 These resources are “undiscovered” and differ from the “proved reserves” cited above.

efficient investment choices, the possibility of lower electric rates, reduced costs of combustion turbine technology to open the door for more companies to sell power, and complexity of monitoring utilities' cost of service and establishing cost-based rates for various customer classes.

The pace of restructuring in the electric power industry slowed significantly in response to market volatility and financial turmoil associated with bankruptcy filings of key energy companies in California. By the end of 2001, restructuring had either been delayed or suspended in eight states that previously enacted legislation or issued regulatory orders for its implementation. Another 18 states that had seriously explored the possibility of deregulation in 2000 reported no legislative or regulatory activity in 2001 (EIA, 2003).

Currently, price deregulation of generation (restructuring) has occurred in 17 states (see Figure 3.13). While the effort is more or less at a standstill, there are Federal efforts in the form of proposed legislation and proposed Federal Energy Regulatory Commission (FERC) actions aimed at reviving restructuring. For states that have not begun restructuring efforts, it is unclear when and at what pace these efforts will proceed.

Figure 3.13: Map of State Electricity Markets, December 2005

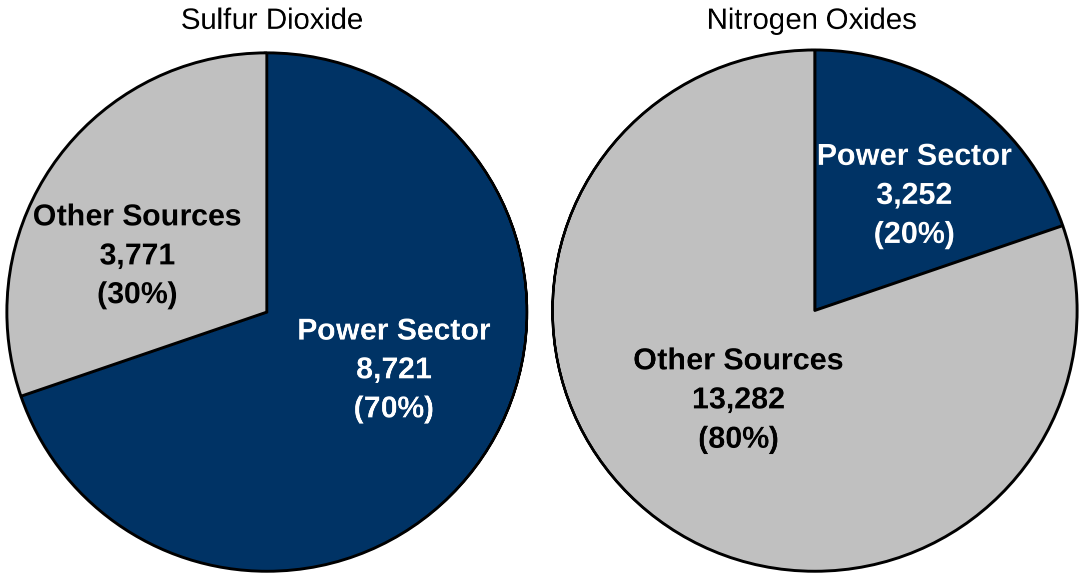


Source: Potter, 2005

US Power Sector Emissions & Emission Controls

The burning of fossil fuels, which generates roughly three-fourths of US electricity nationwide, results in air emissions of SO_2 and NO_X, important precursors in the formation of fine particles and ozone. These pollutants, along with their precursors, are responsible for numerous adverse impacts, including: acid rain, nutrient loading of land and water bodies, decreased visibility, reduction in crop yield, and adverse human health impacts (primarily pulmonary and cardiovascular in nature). The power sector is a major contributor of both SO_2 and NO_X; in 2006, the power sector accounted for 70 percent of total nationwide SO_2 emissions and 20 percent of total nationwide NO_X emissions (see Figure 3.14). Reducing these pollutants is a critical component of EPA's mission to improve human health and the environment (through attainment of National Ambient Air Quality Standards (NAAQS) for fine particle and ozone via programs such as the Clean Air Interstate Rule (CAIR)).

Figure 3.14: Total US Power Sector Sulfur Dioxide and Nitrogen Oxides Emissions, in Thousand Metric Tons, 2006



Source: EPA, 2007c

Different types of fossil fuel-fired units vary widely in their air emissions levels for SO_2 and NO_X, particularly when uncontrolled. For coal-fired units, NO_X emission rates can vary from under 0.05 pounds/million Btu (for a unit with selective catalytic reduction for NO_X removal) to over 1 pound/million Btu for an uncontrolled cyclone boiler. NO_X emissions from coal-fired power plants are formed during combustion and are a result of both nitrogen in coal and nitrogen in the air. SO_2 emission rates can vary from under 0.1 pounds/million Btu (for some units with flue gas desulfurization for SO_2 removal) to over 5 pounds/million Btu for units burning higher sulfur coal. For an uncontrolled coal plant, SO_2 emissions are directly related to the amount of sulfur in the coal.

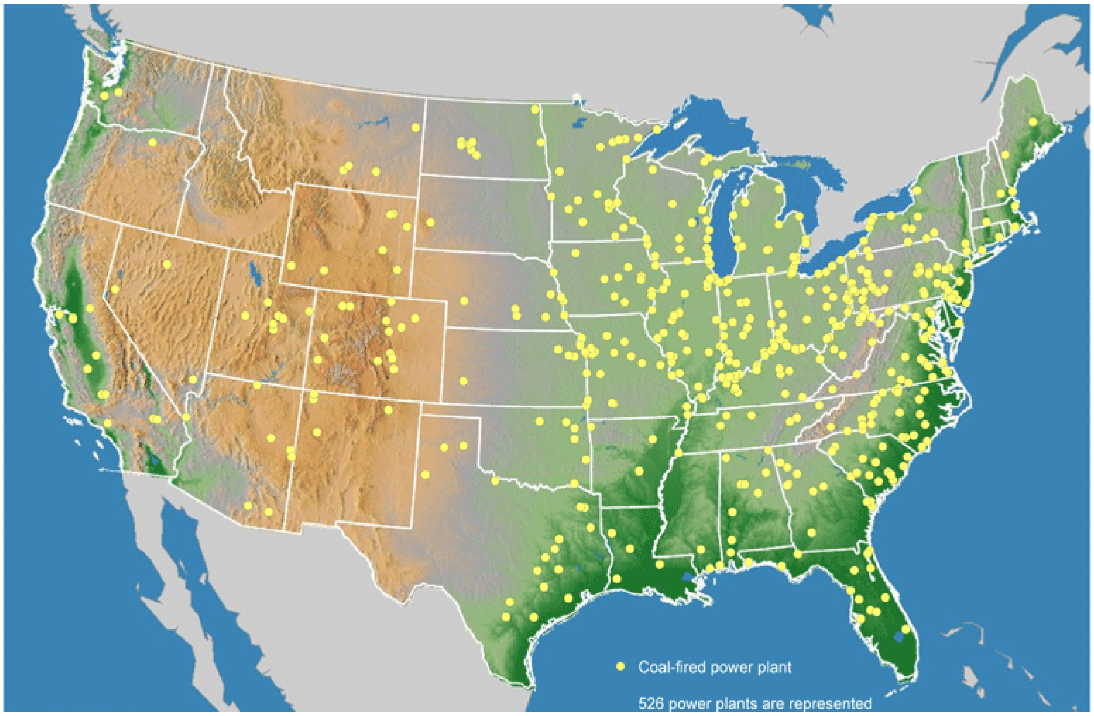
Gas and oil-fired units also have a wide range of NO_X emissions depending on both the plant type and the controls installed. Gas-fired units with selective catalytic reduction (SCR) can have emission rates under 0.01 pounds/million Btu, while completely uncontrolled units can emit in excess of 0.5 pounds/million Btu. Gas-fired units emit very little SO_2. NO_X emission rates on oil-fired units can range from under 0.1 pounds/million Btu (for units with new combustion controls) to over 0.6 pounds/million Btu for units without combustion controls. SO_2 emissions for oil-fired units can range from under 0.1 pounds/million Btu for units burning low sulfur distillate oil to over 2 pounds/million Btu for units burning high sulfur residual oil.

Pollution Control Technologies for Sulfur Dioxide and Nitrogen Oxides

Coal-fired power plants are located throughout the continental US (see Figure 3.15) and represent the vast majority of power sector emissions. In 2006, coal-fired power plants were responsible for 98 percent of electric industry SO_2 emissions and 94 percent of electric industry NO_X emissions. Controlling emissions from these coal-fired plants is thus a central priority for air pollution control from the electric generating sector.

There are two primary options for reducing SO_2 emissions from coal-burning electric power plants. Units may switch from higher to lower sulfur coal, or they may use flue gas desulfurization technology (FGD, commonly referred to as scrubbers). According to data submitted to EPA for compliance with the Title IV Acid Rain Program, the SO_2 emission rates for coal-fired units without FGD varied from under 0.5 pounds/million Btu to over 5 pounds/million Btu, depending on the type of coal combusted. For units with FGD, SO_2 emissions rates were generally within a range of 0.03 pounds/million Btu to 0.5 pounds/million Btu, though some units did exhibit rates outside of this range.

Figure 3.15. Map of US coal-fired power plants, 2003

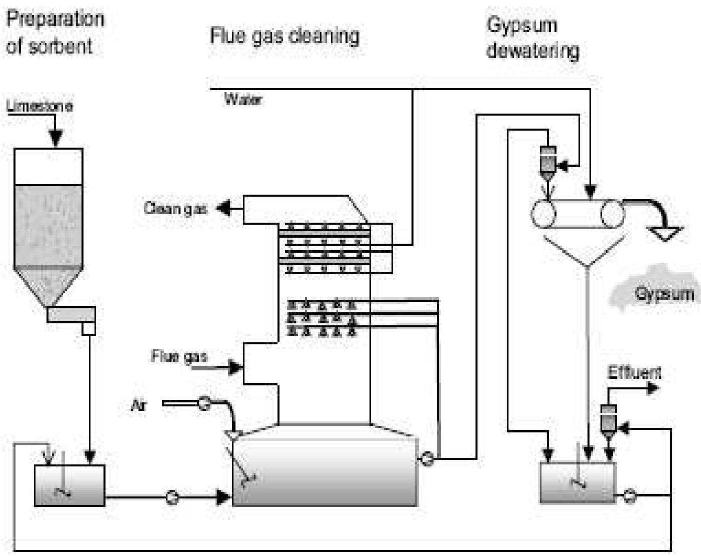


Source: EPA, 2006c

For purposes of reducing SO_2 emissions by switching coal types, it is generally easier to switch to a coal within the same rank (e.g. bituminous or sub-bituminous) because these coals will have similar heat contents and other characteristics. Switching completely to sub-bituminous coal (which typically has a lower sulfur content) from bituminous coal is likely to require some modifications to the unit. Limited blending of sub-bituminous coal with bituminous coal can often be done with much more limited modifications.

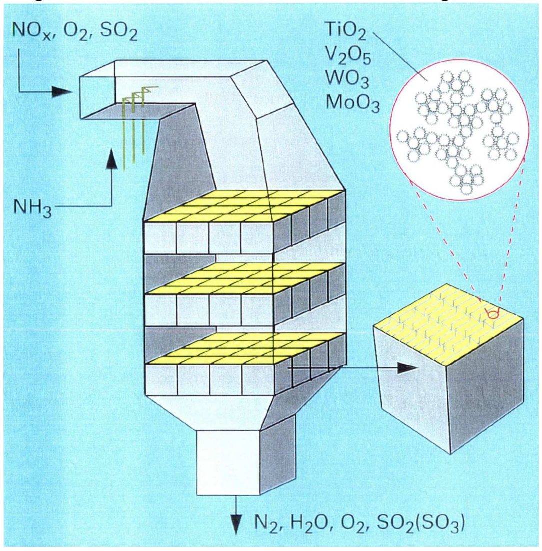
The two most commonly used scrubber types include wet scrubbers and spray dryers (see Figure 3.16). Wet scrubbers can use a variety of sorbents to capture SO_2, including limestone and magnesium enhanced lime. The choice of sorbent can affect the performance, size, and capital and operating costs of the scrubber. New wet scrubbers typically achieve over 95 percent SO_2 removal. Spray dryers can achieve over 90 percent removal.

Figure 3.16: Flue Gas Desulphurization Unit Design Schematic and Example



There are two primary methods for reducing NO_X emissions. One method of reducing NO_X emissions is through the use of combustion controls (such as low NO_X burners and over-fired air). Combustion controls reduce NO_X emissions by ensuring that less NO_X is formed during the combustion of coal occurs under conditions under which less formation of NO_X occurs. The other approach for reducing NO_X emissions is through the use of post-combustion controls, which remove NO_X after it has been formed. The most common post-combustion control is selective catalytic reduction (SCR) technology (see Figure 3.17). SCR systems inject ammonia (NH_3), which combines with the NO_X in the flue gas to form nitrogen and water, using a catalyst to enhance the reaction. These systems can reduce NO_X by as much as 90 percent and achieve emission rates of around 0.06 pounds/million Btu. Selective non-catalytic reduction also removes NO_X by injecting ammonia, but no catalyst is used. These systems can reduce NO_X by up to 40 percent.

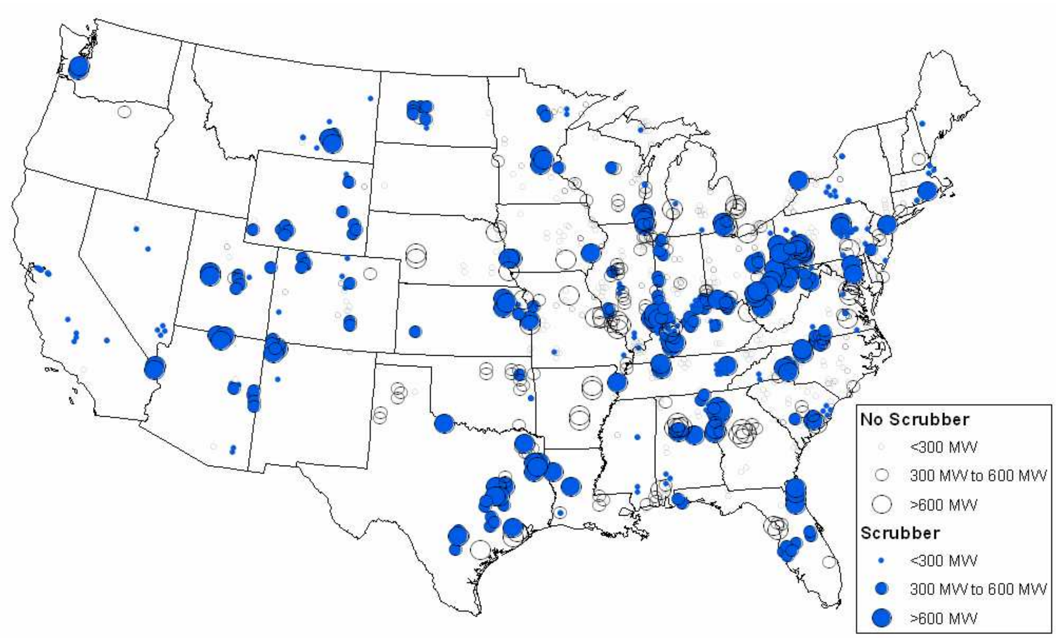
Figure 3.17: SCR Reactor: Design Schematic and Example



In 2006, there were 247 coal units in the US that had scrubbers and 179 that had SCR, representing approximately 100 GW and 93 GW of capacity, respectively. These pollution controls are largely found in the Eastern US, where most of the country's coal-fired capacity is located (see Figures 3.18 and 3.19).

Costs of controlling SO_2 and NO_X vary with a number of different factors. SO_2 control through the use of FGD varies with both generating capacity and heat rate of the electric generating unit. Generally, capital costs and fixed operation and maintenance (O&M) decrease with increasing generating capacity and variable O&M costs hold relatively constant with increasing capacity (though these costs increase slightly with increasing heat rate). Costs of post-combustion NO_X control depend primarily on the type of control used (e.g., SCR or SNCR). See Tables 3.3 and 3.4 for more detailed information.[7] For comparison, see Table 3.5 for new power plant cost and performance estimates.

Figure 3.18: Map of US FGD Operation, by Unit Generating Capacity, 2006[8]

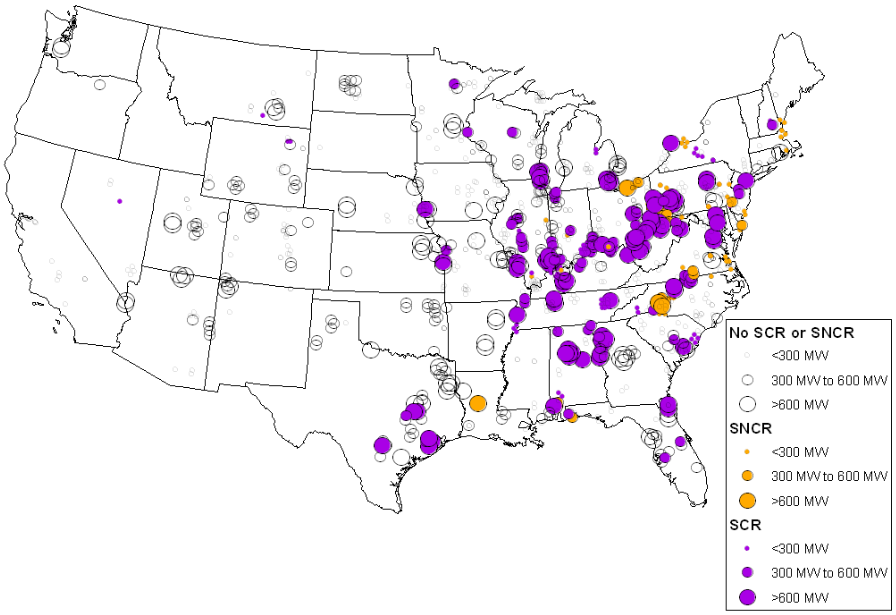


Source: EPA, 2006c

[7] For more detail on EPA's cost and performance assumptions of pollution controls, see the documentation for the Integrated Planning Model (IPM), a dynamic linear programming model that EPA uses to examine air pollution control policies for SO_2 and NO_X throughout the contiguous US for the entire power system. Documentation for IPM can be found at http://www.epa.gov/airmarkets/epa-ipm.

[8] May include control technology currently under construction.

Figure 3.19: Map of US SCR and SNCR Operation, by Unit Generating Capacity, 2006[9]



Source: EPA, 2006c

Table 3.3: Post-Combustion Control Technology Cost and Performance Estimates for NO_X Controls for Coal Plants (2004$)

Post-Combustion Control Technology	Capital ($/kW)	Fixed O&M ($/kW/Yr)	Variable O&M (mills/kWh)	Percent Removal
SCR[10]	111	0.74	0.67	90%
SNCR[11]	Term 1: 19	Term 1: 0.28	0.98	35%
	Term 2: 22	Term 2: 0.33		
SNCR (Cyclone)[12]	11	0.16	1.46	35%
SNCR (Fluidized Bed)[13]	19	0.29	See Footnote 16	50%

Source: EPA, 2006a

9 May include control technology currently under construction.

10 *SCR Cost Scaling Factor* - SCR Capital and Fixed O&M Costs: $(242.72/MW)^{0.27}$; SCR Variable O&M Costs: $(242.72/MW)^{0.11}$; Scaling factor applies up to 600 MW.

11 *SNCR Cost Scaling Factor* - SNCR Capital and Fixed O&M Costs: $(Term1*(200/MW)^{0.577} + Term2*(100/MW)^{0.681})/2$

12 *Cyclone Cost Scaling Factor* - High NO_X Coal SNCR—Cyclone Capital and Fixed O&M Costs: $(300/MW)^{0.577}$; VO&M = 1.27 for MW < 300; VO&M = 1.27 – ((MW – 300)/100) * 0.015 for MW > 300.

13 *Fluidized Bed Cost Scaling Factor* - SNCR - Fluidized Bed Capital and Fixed O&M Costs: $(200/MW)^{0.577}$; VO&M = .85 (fixed).

Table 3.4: Post-Combustion Control Technology Cost and Performance Estimates for SO_2 Controls for Power Plants (2004$)

Scrubber Type	Capacity (MW)	Heat Rate (Btu/kWh)			Costs
		9,000	10,000	11,000	
Limestone Forced Oxidation (LSFO)	100	466	468	470	Capital Cost ($/kW)
Minimum Cutoff: 100 MW		19	19	19	Fixed O&M ($/kW-yr)
Maximum Cutoff: None		1.3	1.4	1.5	Variable O&M (mills/kWh)
Assuming 5.0 pounds/Million Btu SO_2 Coal	300	228	230	232	Capital Cost ($/kW)
		11	11	11	Fixed O&M ($/kW-yr)
		1.3	1.4	1.5	Variable O&M (mills/kWh)
	500	171	174	176	Capital Cost ($/kW)
		9	9	9	Fixed O&M ($/kW-yr)
		1.3	1.4	1.5	Variable O&M (mills/kWh)
	700	140	142	144	Capital Cost ($/kW)
		8	8	8	Fixed O&M ($/kW-yr)
		1.3	1.4	1.5	Variable O&M (mills/kWh)
	1,000	118	120	123	Capital Cost ($/kW)
		7	7	7	Fixed O&M ($/kW-yr)
		1.3	1.4	1.5	Variable O&M (mills/kWh)
Lime Spray Drying (LSD)	100	279	286	293	Capital Cost ($/kW)
Minimum Cutoff: 100 MW		11	13	12	Fixed O&M ($/kW-yr)
Maximum Cutoff: None		2.1	2.4	2.6	Variable O&M (mills/kWh)
Assuming 3.0 pounds/Million Btu SO_2 Coal	300	148	155	163	Capital Cost ($/kW)
		8	8	8	Fixed O&M ($/kW-yr)
		2.1	2.4	2.6	Variable O&M (mills/kWh)
	500	124	131	139	Capital Cost ($/kW)
		6	6	6	Fixed O&M ($/kW-yr)
		2.1	2.4	2.6	Variable O&M (mills/kWh)
	700	111	118	126	Capital Cost ($/kW)
		5	5	5	Fixed O&M ($/kW-yr)
		2.1	2.4	2.6	Variable O&M (mills/kWh)
	1,000	104	112	120	Capital Cost ($/kW)
		4	4	4	Fixed O&M ($/kW-yr)
		2.1	2.4	2.6	Variable O&M (mills/kWh)

Source: EPA, 2006a

Table 3.5: Cost and Performance Estimates for New Power Plants (2004$)[14]

	Conventional Pulverized Coal-Wet Bituminous	Conventional Pulverized Coal-Dry	Integrated Gasification Combined Cycle	Advanced Combined Cycle	Advanced Combustion Turbine	Nuclear
Size (MW)	600	600	550	400	230	1000
First Year Available	2010	2010	2010	2010	2010	2015
Lead Time (in years)	4	4	4	3	2	6
Heat Rate (btu/kwh)	8,661	8,661	7,477	6,403	8,612	10,400
Capital Cost ($/kwh)	1,217	1,300	1,386	555	369	1,913
Fixed O&M (2004$/KW-YR)	37.56	43.96	53.78	15.84	6.51	61.82
Variable O&M ($/MWh)[15]	2.87 - 4.14	3.23 - 4.50	1.70 - 4.43	2.41 - 7.01	2.38 - 8.76	0.45

Source: US EPA, 2006a

4. US Policies & Programs to Control Sulfur Dioxide and Nitrogen Oxides Emissions from the Electric Power Sector

Efforts to control emissions in the US began as early as the 1880s as several industrialized cities began to restrict smoke opacity. However, it wasn't until many decades later in the 1960s and 1970s that the US started to transition from limited and uneven air quality management approaches at the local level to uniform standards and emission control strategies implemented through a collaborative federal approach between local-, state-, and national-level governments.

In 1970, the US Congress passed the landmark Clean Air Act (CAA) to reduce air pollution impacts on human health and the environment. The CAA established a number of new programs to measure and improve air quality, including primary and secondary NAAQS, a state-level planning process for air quality management, and technology and performance standards for stationary and mobile sources (see Figure 4.1). Much of the air quality management framework established in the 1970 CAA is still in use today (Bachman, 2007).

Although the CAA and subsequent amendments include a number of specific programs to control emissions from stationary sources, the approaches can be grouped into three broad categories: (1) technology mandates, (2) emission performance standards, and (3) cap and trade programs. The first approach, technology mandates, typically mandates the installation and operation of specific emission control technologies (e.g., flue-gas desulfurization (FGD) or scrubbers for controlling SO_2). In contrast to a technology mandate, an emission performance standard simply specifies a maximum allowable emission rate (e.g., grams per million British thermal units (Btu) of heat input) from a specific type of emission source. The source owners and operators have the flexibility to implement any combination of technologies and operational

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14 Reflects inclusion of advanced SO_2 and NO_X controls, such as FGD and SCR

15 Varies by segment; values shown represent a range.

practices to meet the standard. The third and more recent approach, cap and trade, provides a cap, or limit, on total cumulative emissions from a group of emission sources (e.g., the electric power sector) in a given geographic area for a specific time period (e.g., calendar year). Each emission source is allocated a quantity of tradable allowances – authorizations to emit a specific quantity of a pollutant (e.g., one short ton of SO_2) – that, in the aggregate, are equal to the cap. Each emission source's operator has the flexibility to develop a compliance strategy that accounts for their facility's design, operational, management, and financial conditions. The compliance strategy for the emission source may include conventional pollution control equipment, process changes, fuel substitution, the purchase of allowances from another emission source, or some combination of the above options that leads to lower compliance costs.

Assessments of the overall human health and environmental benefits and economic costs of these programs indicate, despite uncertainties, that implementation of the CAA has had substantial net economic benefits. A retrospective study assessing the benefits and costs of the 1970 CAA and 1977 CAA Amendments estimated benefits to human health, human welfare, and the environment exceeded the actual costs of achieving the pollution reductions by a ratio of more than 40 to one (EPA, 1997). A prospective study assessing the benefits and costs of the 1990 CAA Amendments estimated that benefits of air pollution control programs, excluding stratospheric ozone protection, outweigh costs by a ratio of four to one (EPA, 1999). These studies also demonstrated that major improvements could be made in US air quality without large economic impacts as these improvements occurred during a time of sustained growth in the economy, population, energy consumption, and vehicle travel (see Figure 4.2).

Figure 4.1: Key Provisions and Authorities of the Clean Air Act

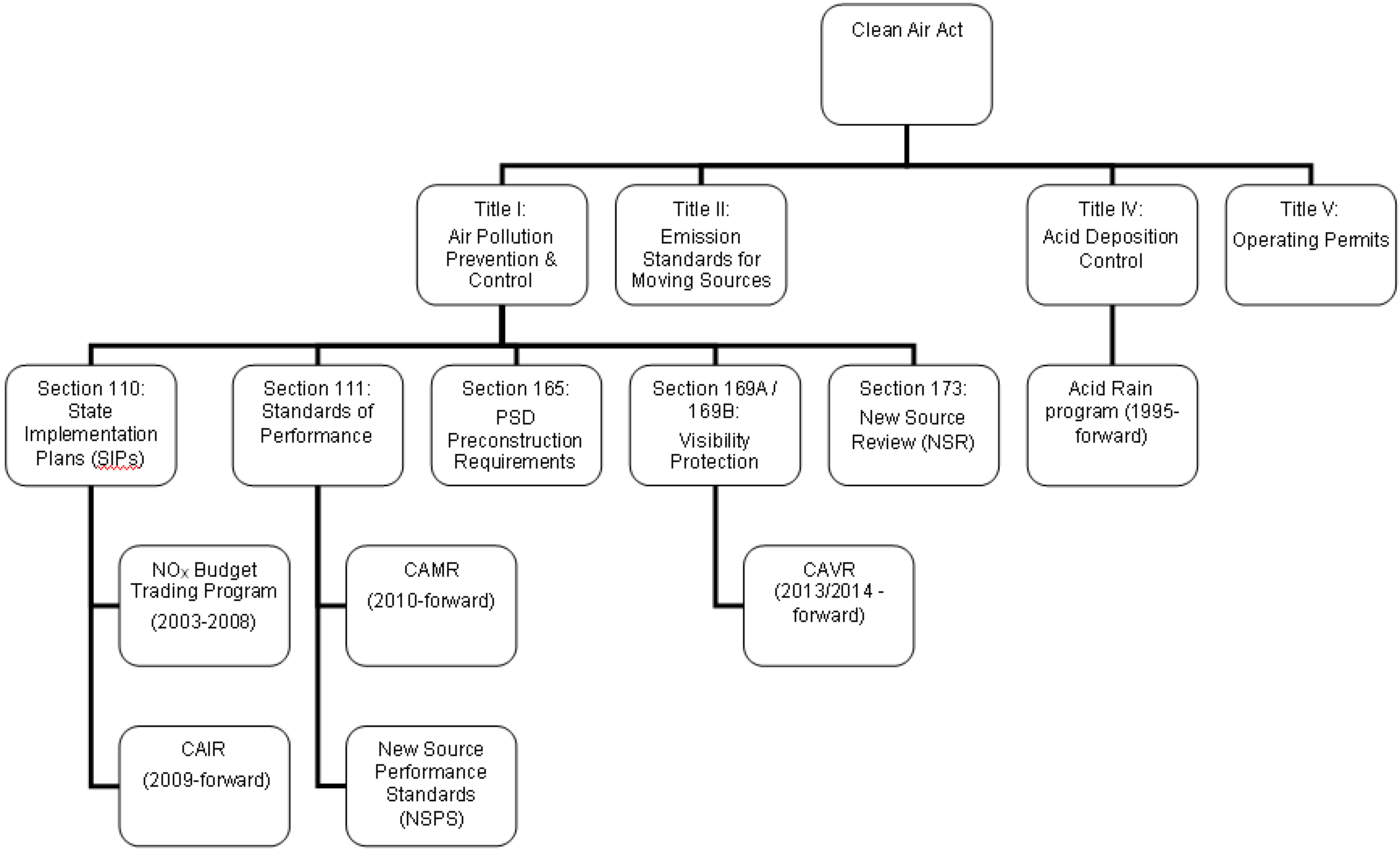
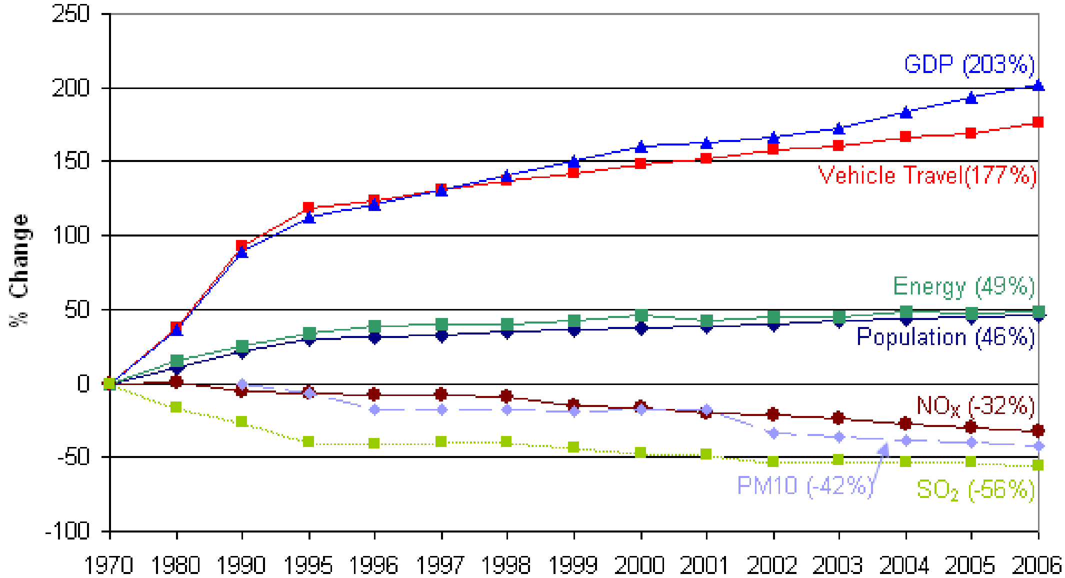


Figure 4.2: Comparison of Trends in Emissions, GDP, VMT, Energy and Population, 1970 – 2006



Source: EPA, 2007f

Air Quality Standards and the Implementation Planning Process

The foundation of the US air quality management approach is a set of standards for six "criteria" air pollutants – SO_2, coarse and fine particulate matter, nitrogen dioxide, ozone, lead, and carbon monoxide (see Table 4.1). EPA establishes NAAQS to protect human health and welfare by limiting concentrations of certain pollutants in the ambient air. Rather than regulating individual emission sources, the NAAQS focus on local and regional air quality and require each state to develop a detailed State Implementation Plan (SIP) indicating how it will achieve the NAAQS. The SIP can be considered a "blueprint for clean air," describing policies, standards, and programs in the state to achieve the air quality targets. The planning process helps state governments develop a strategic, integrated approach to achieve air quality goals.

Table 4.1: US National Ambient Air Quality Standards

Pollutant	Averaging Time	Primary NAAQS ($\mu g/m^3$)
Sulfur Dioxide (SO_2)	1 year	80
	24 hours	365
Particulate Matter ≤ 10 microns	24 hours	150
Particulate Matter ≤ 2.5 microns	1 year	15
	24 hours	35
Nitrogen Dioxide (NO_2)	1 year	100
Ozone (O_3)	8 hours	160
Lead	3 months	1.5
Carbon Monoxide (CO)	8 hours	10,000
	1 hour	40,000

Each SIP provides specific emission limits and compliance timetables for relevant emission sources in the state, establishes procedures for monitoring air quality, and outlines enforcement capabilities and procedures. While state governments must adhere to federal requirements, the CAA gives them some freedom to decide which emission sources and sectors should be included in the state air quality management programs. Additionally, states can choose the method of regulation, such as technology standards, performance standards, or cap and trade programs.

Once a SIP is approved by EPA, the requirements in the SIP become federally enforceable, meaning the state and EPA have the authority to enforce provisions of the plan and penalize sources that are in non-compliance. In addition, EPA can penalize state governments that are not in compliance with the NAAQS by specified dates. Mandatory sanctions for non-compliance include: (1) limiting new facility development by requiring new emission sources to purchase emission offsets from existing sources at a two-to-one ratio (which has the practical effect of severely limiting growth of new facilities) and (2) withholding federal highway funds from the affected areas.

Challenges of the State Implementation Plan Process

The SIP process is an important and essential component of air quality management in the US. A comprehensive SIP is a useful exercise and provides policymakers with critical information that is essential to developing an air quality management plan. In addition, the SIP requirements for emission inventories and air quality modeling have led to the development of uniform methods for quantifying emissions and promoted the development of increasingly sophisticated air quality models, such as the models used for the JES. Nevertheless, the SIP process has presented a number of challenges to state governments and EPA. Those challenges include:

- The SIP process has become overly bureaucratic, taking time and resources away from the more important issue of controlling emissions and tracking progress toward attainment of the NAAQS (NRC, 2004);
- The SIP process uses models to predict the impact of existing and future programs on future air quality, but does not include a simple iterative process to update data and assumptions to reflect new information and scientific tools;
- Programs can be very prescriptive and can stifle innovation (NRC, 2004); and
- A focus on individual pollutants that make it difficult to consider multi-pollutant approaches that may be more effective, both in terms of air quality improvements and compliance costs (NRC, 2004).

The US air quality management system might benefit from a more streamlined, flexible, holistic, and integrated approach to the SIP planning process. Reports by the National Research Council of the National Academies (2004) and Air Quality Management Working Group (2005) recommend that the US SIP process be transformed to: 1) place a greater emphasis on performance and results, 2) encourage multipollutant control strategies, 3) allow for a streamlined, iterative process for updating and modifying SIPs, 4) provide more flexibility for innovative emission control measures, and 5) require periodic assessments to ensure that areas are making progress toward attaining the NAAQS.

Operating Permits, Technology Mandates, and Performance Standards

In addition to the state-specific policies contained in the SIP, the CAA (Title V) requires states to establish and manage permit programs to control emissions from major emission sources. Under the permit program, each new or modified major emission source must apply for a permit before beginning construction. The permits contain detailed emission control requirements, including technology- and performance-based requirements, compliance schedules, monitoring requirements, and other conditions found in the CAA or SIP. Some of the key emission control provisions in the CAA that apply to the permit include New Source Performance Standards (NSPS), New Source Review (NSR), and Prevention of Significant Deterioration (PSD).

The first provision, NSPS, establishes performance standards, typically expressed as a maximum emission rate in pounds per million Btu for major and minor sources on a category-by-category basis. NSPS are uniform national standards (see Table 4.2) that EPA is required to progressively tightens over time to, in theory, achieve a steady rate of air quality improvement without unreasonable economic disruption.

Table 4.2: Select US New Source Performance Standards – Emission Limits for Fossil-Fuel Fired Electric Power Plants

Stationary source type	Unit Size Threshold	SO_2 Limit value	NO_X Limit Value
Fossil-fuel electric power plants (constructed after 1971 August 17)	Heat input capacity > 250 million Btu per hour	*Coal*: 544 grams per million Btu *Oil and gas*: 363 grams per million Btu	*Coal*: 318 grams per million Btu *Oil*: 136 grams per million Btu *Gas*: 91 grams per million Btu
Fossil-fuel electric power plants (constructed after 1978 September 18)	Heat input capacity > 250 million Btu per hour	Coal: 544 grams per million Btu and controlled to 90% below potential concentration or 272 grams per million Btu and controlled to 70% below potential concentration Oil and gas: 363 grams per million Btu and controlled to 90% below potential concentration or 91 grams per million Btu	*Coal*: 227 grams per million Btu *Oil*: 136 grams per million Btu *Gas*: 91 grams per million Btu

40 CFR 60.40 (2007)

The second provision, NSR, applies to areas that do not attain the NAAQS. Under NSR, new or modified major emission sources in nonattainment areas must meet strict emission control requirements. The requirements include installing and operating emission control equipment that has the lowest achievable emission rate (LAER) (see Table 4.3). LAER is based on either (1) the most stringent emission limit in any SIP for the class or category of emission source or (2) the most stringent emission limit achieved for a certain class or category of emission source (NRC, 2004). LAER does not consider equipment or operating costs when establishing the control requirement. In addition to the technology requirement, the emission source must offset its emissions from the proposed new or modified facility with the purchase of emission reduction credits (ERCs).

The ERCs are created by reducing emissions from other emission sources in an amount greater than the permitted emissions of the new or modified emission source. This means that, for every ton of regulated pollutants that a new or modified source is permitted to emit, another source in the vicinity must reduce its emissions by more than one ton of pollution. The emission offset must be greater than the permitted emission increase from the proposed project in order to ensure progress toward attainment of the NAAQS. In this way, the regulation helps non-attainment areas move closer to meeting the NAAQS requirement while offering emission sources some flexibility and allowing for industrial and economic growth.

The final provision, PSD, is a program for emission sources in areas that already meet the NAAQS. It was designed to ensure that additional emissions from new and modified major emission sources do not lead to deteriorating air quality. It also serves to counteract the unintended incentive of the NSR program for high-pollution industries to relocate to less-polluted states to avoid NSR permitting requirements. PSD, like NSR, requires new facilities to install and operate specific technologies. PSD standards, however, require the installation of best available control technology (BACT), which take into account energy, environmental, and economic impacts, as well as other costs (NRC, 2004). Thus, the control technology requirements under BACT can be less stringent than those under LAER. Moreover, PSD does not require emission offsets from existing emission sources in the vicinity.

Table 4.3: US Emission Control Technology Requirements for Power Plants

	New or Modified[16] Source	Existing Source
NAAQS Attainment Area (PSD Provision)	Best available control technology (BACT)	None
NAAQS Non-attainment Area (NSR Provision)	Lowest achievable emission rate (LAER) Emission offsets	Reasonably available control technology (RACT)

Challenges of Technology Mandates and Performance Standards

The NSR and PSD provisions have contributed to emission reductions from large stationary emission sources without constraining economic development. In areas that do not attain the NAAQS, the NSR provision provides a mechanism for construction of new emission sources to proceed without undermining efforts to attain the NAAQS.

[16] Control technology requirements are applicable to any existing emission source that has made a "major" modification that increases the source's potential emissions.

Both provisions mandate the installation and operation of emission control technologies and practices in new and modified emission sources and, in the case of emission “offsets” in the NSR provision, result in a net decrease in total emissions. However, the NSR and PSD provisions have some limitations as well. Some of the more challenging aspects of the provisions include:

- *Complexity and Inefficiency*. The NSR and PSD permitting process has become complex and time consuming. Representatives of industry complain that the process fosters inefficiencies and unduly discourages economic growth and innovation (NRC, 2004).
- *Lack of Emission Controls for Existing Emission Sources*. The NSR and PSD provisions of the 1970 CAA did not require emission control technologies on existing emission sources, in effect “grandfathering” these facilities. These sources were exempted from emission control requirements because (1) installing controls on these emission sources would be costly for both electricity generators and customers; (2) it would be more efficient to install these devices on new electric power plants; and (3) the old electric power plants were nearing the end of their operating lifetimes and would be retired soon, paving the way for new facilities in which the pollution control technology is required (NRC, 2004). Experience has shown, however, that many emission sources continue to operate with minimal modernization well after the expected 30-year operating life. The relatively high cost of retrofitting facilities to control emissions and the existence of a complex system of requirements for new, modified, and existing facilities has provided incentives for not retiring or modifying facilities (Hsu, 2006).
- *Uncertainty*. The NSR provision requires emission control technologies on new and modified major emission sources. The provisions, however, lack a clear definition of a “major modification” which would establish the emission control obligation on an existing emission source. This has led to costly and time consuming litigation.
- *Cumbersome administration and high transaction costs*. New and modified emission sources in areas that do not meet the NAAQS are required to offset permitted emissions by purchasing ERCs from existing emission sources that have reduced emissions. To be certified as credible, the relevant state environment agency must determine that the emission reduction: (1) is not required by existing regulations (i.e., surplus) (2) can be measured (i.e., quantifiable), (3) will endure for the life of the ERC (i.e., permanent), (4) represents real reductions, not “paper” reductions, and (5) the emission reduction and its corresponding new emission limit are legally and practically enforceable by the government. In addition, because this program was focused on local, not regional or national emission reductions, it was often necessary to assure that air quality would not deteriorate because of the trade; a process that could be time consuming and resource intensive. These challenges not only limited the usefulness of the “offset” programs, they also created relatively high transaction costs (ETEI, 1999) and long approval timelines for trades (EPA, 2001).

Regional Haze

The CAA established special visibility goals for national parks and wilderness areas (Class I areas). The 1977 CAA Amendments set a national goal for visibility in these areas as “the prevention of any future, and the remedying of any existing, impairment of visibility…which impairment results from manmade air pollution.” EPA was given the authority to issue regulations to assure “reasonable progress” toward meeting the national goal.

EPA’s efforts started with regulations to address single emission sources or small groups of emission sources that contribute to a specific visibility problem. Those regulations were only the first phase of programs to address visibility problems. EPA, working with other government agencies such as the National Park Service, worked to improve monitoring and modeling techniques in an effort to improve the scientific understanding of the pollutants and emission sources that contribute to the visibility problems.

In 1999, EPA issued the regional haze rule. The rule sets specific visibility improvement targets for the nation, but states are required to develop plans (SIPs) to achieve “reasonable progress” toward the goals (NRC, 2004). Under this rule, all states are required to submit SIPs, even states that do not have Class I areas with a visibility problem. In these states, the SIPs focus on reducing in-state emissions that contribute to visibility degradation elsewhere. Thus, like the NO_X SIP Call that established the NO_X Budget Trading Program, EPA’s regional haze rule attempts to address a regional air pollution problem by requiring action from all contributors to an air quality problem.

Although the rule requires all states to participate, it does not impose specific intra- or interstate emission controls or limits. Instead, all but nine Western states[17] are required to develop long-term strategies for achieving the visibility improvement goals set by EPA and to submit these strategies in the form of a regional haze SIP to EPA for approval and review (NRC, 2004).

The regional haze rule gives states the option of developing their own implementation plans but encourages them to work collaboratively with other states by forming Regional Planning Organizations. Today there are five regional planning organizations addressing regional haze (NRC, 2004). Some states, such as those in the Western Regional Partnership have proposed a cap and trade program to control the emissions that contribute to visibility impairment.

Cap and Trade

The US experience has shown that, when conditions are right for traditional regulation, such as technology or performance standards, these programs can lead to significant emission reductions. However, in some circumstances, these traditional regulations can be expensive and resource intensive. These shortfalls often stem from the inflexibility of “one-size-fits-all” standards that offer little flexibility to determine the best, most cost-effective emission control options. Recognizing this, legislation and regulation in the US have evolved to include more flexibility in the form of market-based policies. While the early experiences with market-based programs, such as ERCs, facility-wide emission limits (“bubbles”), and company fleet averaging programs, were modest, they nonetheless paved the way for the cap and trade programs. Current cap and trade programs include the Acid Rain Program, NO_X Budget Trading Program, CAIR, and CAVR.

Unlike the early market-based programs that were designed as an addition to technology or performance standards in an effort to reduce the cost of compliance, the cap and trade approach was designed as a stand-alone program to reduce emissions across a broad region from a group of emission sources (e.g., electric power plants).

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[17] The nine Western states are treated in a separate section of the regional haze rule because they contribute to visibility impairment in the Grand Canyon area.

The approach does not, however, replace existing technology and performance requirements that were designed to protect local air quality and help regions attain the NAAQS by establishing specific, minimum control or performance levels for each emission source. Instead, cap and trade and other program approaches are designed to complement, not contradict, one another.

In the 1990 CAA Amendments (Title IV), the US Congress, considering the potential economic and environmental benefits of a credible, effective emission trading program and the lessons from the early emission "offsets" program, created the Acid Rain Program – the world's first large-scale cap and trade program for air pollution. The program was designed to reduce the adverse ecological effects of acid rain by requiring substantial reductions of SO_2 and NO_X emissions from the electric power sector in the contiguous US. Today, it covers approximately 3,550 electricity generating units.

Under the Acid Rain Program, the electric power sector's SO_2 emissions were capped at 9.05 million metric tons for the year 2000. The cap gradually declines to 8.14 million metric tons per year in 2010. EPA is responsible for creating allowances – authorizations to emit a specific quantity of pollution (e.g., one short ton) – equal to the level of the cap and distributing the allowances to emission sources using a prescribed formula. The emission source owners and operators have the flexibility to develop compliance strategies that account for relevant conditions at their respective electric power plant. The compliance strategies may include installing pollution controls, switching fuels, changing processes, and/or buying surplus emission allowances from emission sources that have reduced emissions more than necessary. In addition to the SO_2 reduction requirements, coal-fired electric generation units have to meet NO_X emission standards individually or through participation in a company-wide emission averaging program that provides a way to achieve NO_X reductions more cost-effectively. Throughout the year, electric power plants must measure their SO_2, NO_X, and CO_2 emissions and report the emission data and supplemental operations data[18] to EPA. At the end of each compliance period, each emission source must hold sufficient allowances to compensate for its emissions during the compliance period.

If an emission source does not hold sufficient allowances to offset its SO_2 emissions, each short ton of excess SO_2 emission is subject to a penalty of $3,152[19] for the 2006 compliance year and the surrender of one future allowance from the source's account to make the environment whole.

The Acid Rain Program has produced more reductions more rapidly and at a lower cost than anticipated when the legislation was passed. A recent study estimated that the human health and environmental benefits of the program exceed the compliance costs by a factor of 40 to one (Chestnut and Mills, 2005). Because of the program's success, it has been held up as a model approach for cost-effectively achieving broad, regional reductions of emissions from large stationary emission sources.

In October 1998, EPA, in collaboration with state governments in the Eastern US, finalized a rule establishing the NO_X Budget Trading Program – a cap and trade program

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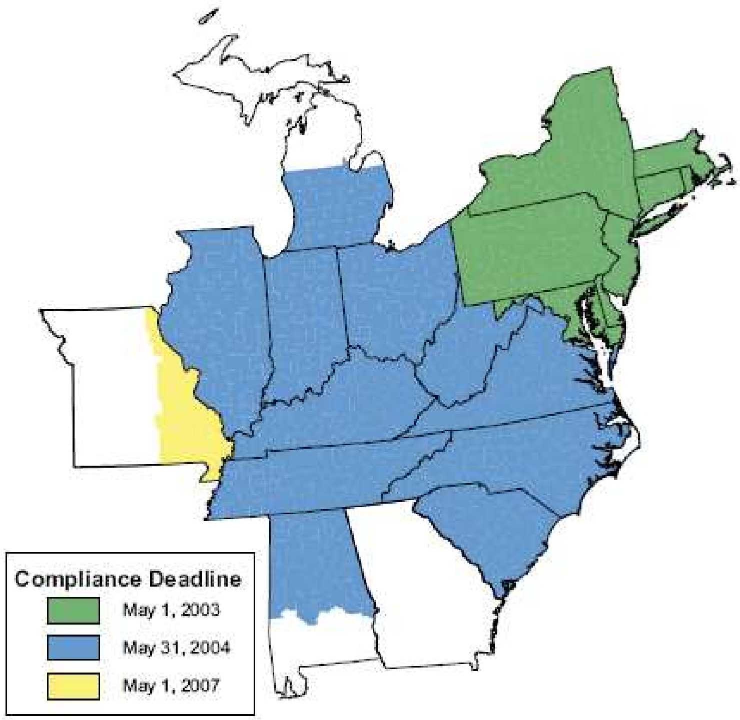
[18] The majority of emission sources are required to provide supplemental data that may include the flow rate of exhaust gases, operating hours, heat input, and calibration and equipment test results. These supplemental data are used by EPA to audit the emission data to ensure accuracy and to assess whether the measurement equipment is properly operated and maintained.

[19] The CAA established a penalty of $2,000 per short ton with a requirement that EPA adjust the penalty amount to reflect inflation. For compliance year 2006, the penalty was $3,152 per short ton ($2,859 per metric ton).

to reduce interstate transport of ozone-season (i.e., summertime) NO_X pollution that contributes to ground-level ozone formation in the Eastern US (see Figure 4.3). For the states participating in the NO_X Budget Trading Program, ozone-season NO_X emission from electric power plants and select industrial boilers are limited by an emission cap. And, as with the Acid Rain Program, emission sources have the flexibility to develop cost-effective compliance strategies to achieve the emission target, including the buying and selling of emission allowances.

Figure 4.3: NO_X Budget Trading Program Region



Source: EPA, 2007d

Unlike the Acid Rain Program, EPA lacked a law specifically establishing the NO_X Budget Trading Program. The Program was established through existing authorities of the CAA. First, EPA established NO_X emission "budgets" – a limit, or cap, on ozone-season emissions of NO_X from electric power plants and select industrial sources – for select Eastern states. Then, under the SIP requirements of the CAA, states were required to issue regulations to reduce seasonal NO_X emissions at or below the state's budget. States were given the flexibility to develop compliance strategies, including an optional cap and trade program. The approach helps states to meet their emission budgets in a cost-effective manner through participation in a region-wide cap and trade program. As of the 2006 ozone season, all affected states and the District of Columbia chose to meet their requirements through participation in the NO_X Budget Trading Program.

Each state issued a regulation based on EPA's model rule, which included provisions for determining which emission sources were required to participate in the program, methodologies for distributing emission allowances, requirements for measuring and reporting emissions, trading protocols allowing allowance banking and unrestricted trading across jurisdictions, and penalties for non-compliance. States had the ability to modify certain provisions within their state rule that would not affect the environmental integrity of the region-wide program, such as allowance allocation methodologies, while critical provisions were required of all states without modification (Napolitano et al., 2007b).

EPA provided states the opportunity to develop state-specific allowance allocation approaches. This was possible because, in general, the states did not have ownership in the emission sources and therefore did not have a conflict of interest. If, however, the states had full or partial ownership in some of the emission sources that would have created a conflict of interest that might corrupt the system.

The NO_X Budget Trading Program is a partnership between EPA and the state environment agencies. While EPA administers the cap and trade program for the 2,579 affected emission sources (electricity generating units and select industrial boilers) (EPA, 2007d), states share responsibility with EPA by allocating emission allowances to the emission sources, inspecting and auditing emission measurement equipment and practices at the emission sources, and enforcing program rules.

If an emission source does not hold sufficient allowances to offset its NO_X emissions, each short ton of excess NO_X emission is subject to a penalty of three future allowances from the source's account to make the environment whole.

At full implementation, the NO_X Budget Trading Program mandates regional ozone-season NO_X reductions of 1.1 million metric tons, or 28 percent of the NO_X emissions in 1990.

Despite the historic and projected benefits of the Acid Rain Program and NO_X Budget Trading Program, recent studies of pollution exposure and human health, data from long-term monitoring networks, scientific information about pollutant fate and transport, and ecological assessments have revealed a need for additional emission reductions to help some areas attain the NAAQS for ozone and fine particulates, and to address regional haze and airborne toxics from various sectors.

For the power sector to achieve the necessary emission reductions and address the interstate transport of ozone and fine particulate pollution in the Eastern US, EPA promulgated the Clean Air Interstate Rule (CAIR) in spring 2005. EPA also published the Clean Air Visibility Rule (CAVR) in spring 2005. When fully implemented over the next 15 to 20 years, CAIR will reduce electric power sector SO_2 and NO_X emissions by approximately 70 percent and 60 percent, respectively, below 2003 levels. The CAVR supplements CAIR by requiring electric power plants, industrial boilers, and select industrial plants (such as pulp mills, refineries, and smelters) to install emission controls known as best available retrofit technology (BART). BART reduces direct PM2.5 emissions and its precursors (SO_2, NO_X, volatile organic compounds, and ammonia) in order to improve visibility in national parks and wilderness areas. The CAVR also includes a cap and trade option for Western States. In addition, emission sources in the Eastern US can satisfy CAVR requirements through compliance with the CAIR requirements.

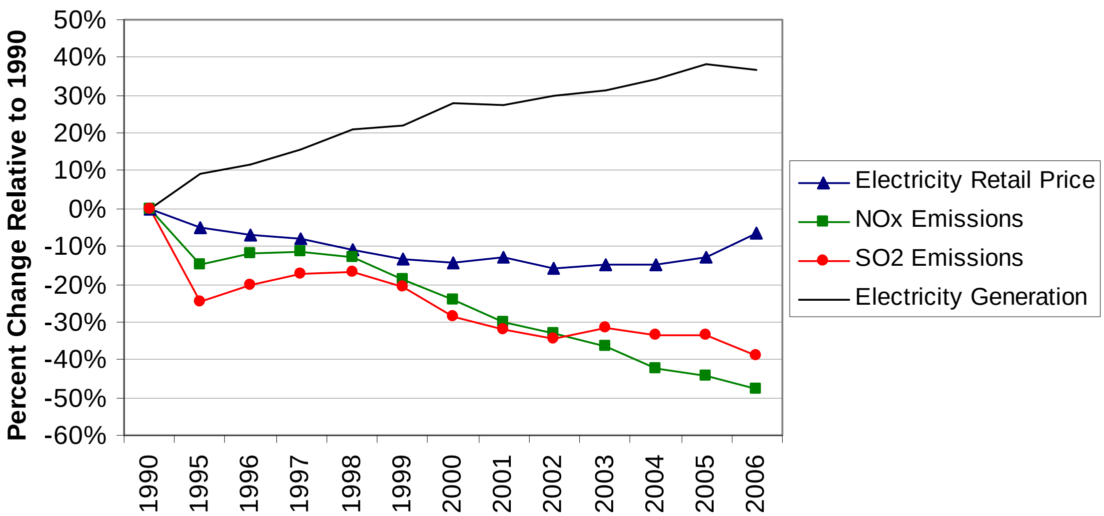
Notably, additional emission control requirements for SO_2, NO_X, and mercury emissions from the electric power sector are necessary to meet the NAAQS, visibility goals, and state-required mercury limits. For direct particulate matter emissions, the SIP process with the state environment agencies in the 1980s led to substantial installation of control technologies through the country and, therefore, no additional federal efforts have been needed for direct particulate matter emissions.

The US cap and trade programs are examples of successful emission control programs that have a) cost effectively reduced emissions from the affected emission sources, b) contributed to significant environmental and human health benefits, and c) fostered a culture of cooperation between government and industry, leading to almost 100 percent compliance. As a result, governments around the world have studied and adopted cap and trade approaches to control emissions of various pollutants (e.g., SO_2, NO_X, particulate matter, and CO_2). The results of the Acid Rain Program and NO_X Budget Trading Program are presented below.

Acid Rain Program Results

Between 1990 and 2006, SO_2 emissions from the electric power sector declined almost 40 percent (5.44 million metric tons) despite a 37 percent increase in power generation (Napolitano et al., 2007a). The provisions in the Acid Rain Program to control NO_X from coal-fired electric power plants, in conjunction with other NO_X control policies, led to a 48 percent (2.92 million metric tons) decline in electric power sector NO_X emissions. Because both the SO_2 and NO_X control requirements provided flexibility for emission sources to develop low-cost compliance strategies, the impact on electricity prices was minimal – retail electricity prices in 2006 were, on average, seven percent below 1990 prices (see Figure 4.4).

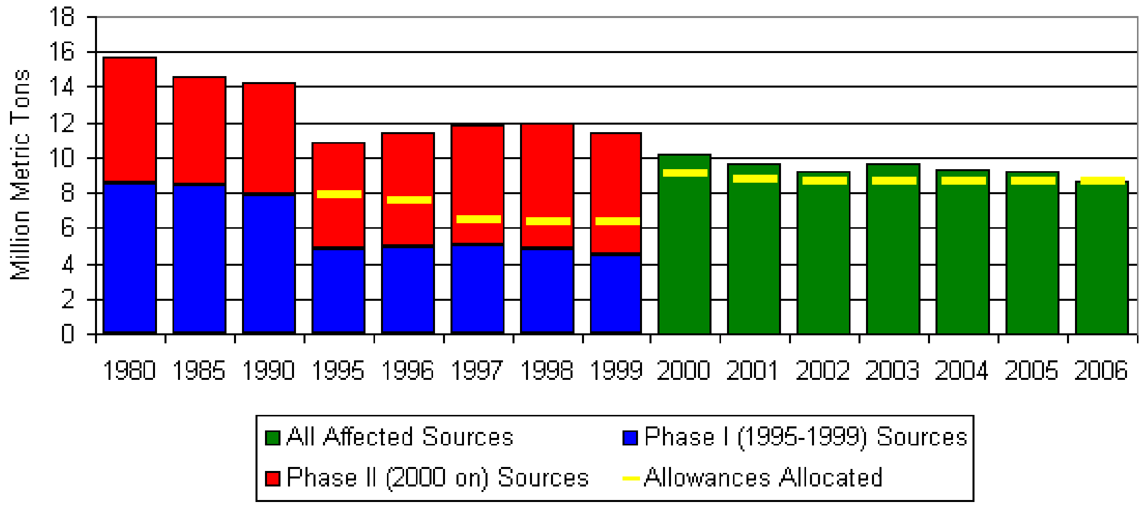
Figure 4.4: US Trends in Electricity Generation, Pricing, and Emissions from the Electric Power Sector, 1990 – 2006



Source: Napolitano et al., 2007a

Emission sources are on target to achieve the emission reduction goal of the Acid Rain Program. During the five years of the Acid Rain Program's first phase, beginning in 1995, the affected electricity generating units reduced emissions by 10.6 million metric tons more than the allowable emission level (see Figure 4.5). The surplus, early reductions freed up allowances that the emission sources banked for future use in the second phase, which began in 2000. As shown in Figure 4.5, emissions in the early years of the second phase were slightly higher than allowable levels as emission sources used the banked allowances from the first phase to smooth the transition to the lower cap levels. In 2006, SO_2 emissions were approximately 0.1 million metric tons below the cap – number of allowances allocated to all emission sources.

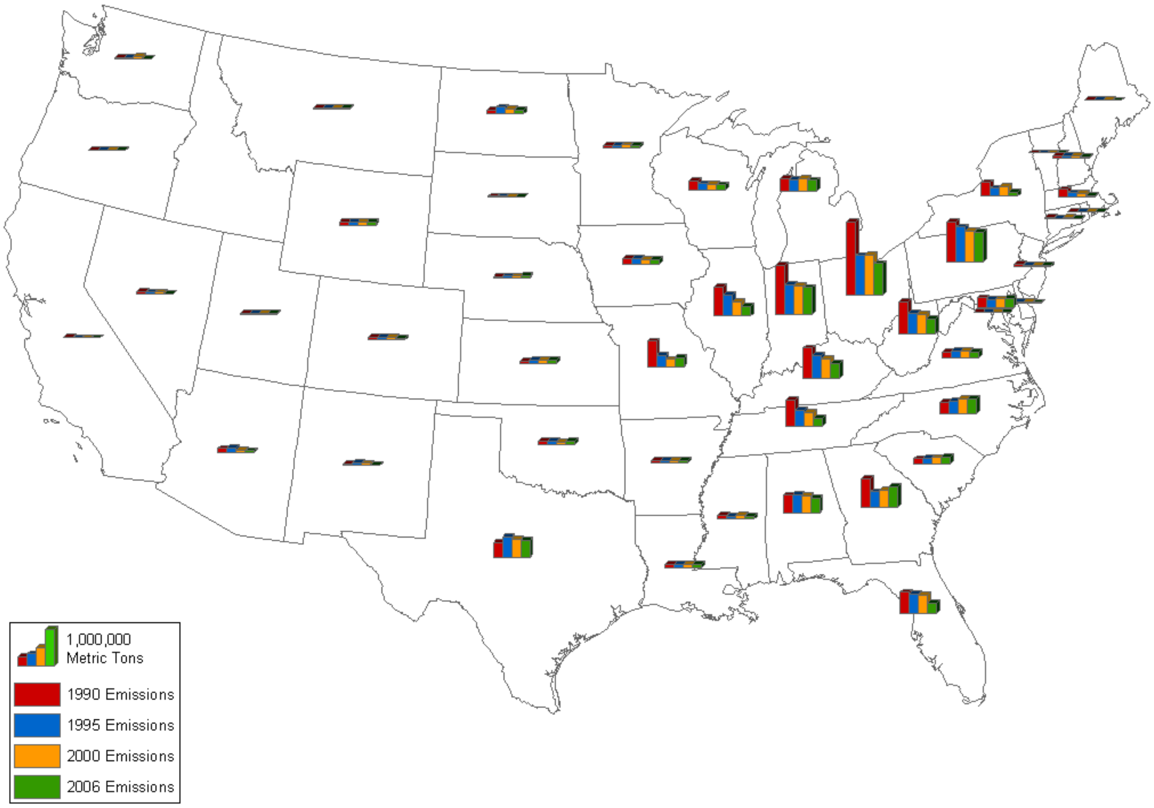
Figure 4.5: Annual SO_2 Emissions from Acid Rain Program Emission Sources, 1980-2006



Source: EPA, 2007a

A review of state-by-state emissions from 1990 to 2006 indicates that the states with the highest SO_2 emissions in 1990 have experienced the greatest SO_2 reductions under the program (EPA, 2007a). This has benefits for downwind states which suffer from the impacts of emissions from other states, sometimes hundreds of kilometers away. While not all states have reduced SO_2 emissions under the program, net emissions in the US have decreased significantly. Sources in 32 states and the District of Columbia have reduced total annual SO_2 emissions by about 6.1 million metric tons. The 16 states that experienced increases – largely due to growth and not increases in emissions rates – did so in much smaller increments, increasing total SO_2 emissions by less than 300,000 metric tons (see Figure 4.6).

Figure 4.6: State-by-State SO_2 Emission Levels, 1990-2006

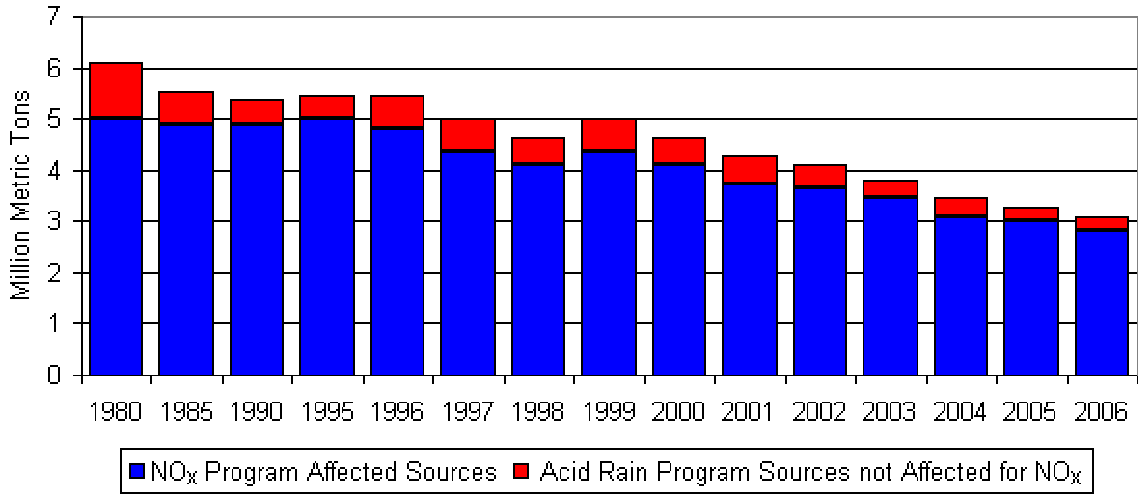


Source: EPA, 2007a

In addition to the SO_2 emission cap, the Acid Rain Program includes a rate-based NO_X emission limit based on boiler type. Under this portion of the program, owners and operators of coal-fired power plants can meet the NO_X limits for each individual unit or average emission rates for groups of units that share a common owner and designated representative.

The objective of the Acid Rain Program NO_X provision is a 1.8 million metric ton annual reduction of NO_X from projected year 2000 emission levels (7.3 million metric tons). The emission sources affected by the NO_X provision met the goal of 5.5 million metric tons in 2000 and every year thereafter (see Figure 4.7). In 2006, NO_X emissions from all Acid Rain Program sources were 3.1 million metric tons. This is approximately 60 percent lower than the projected year 2000 NO_X emission levels. These reductions occurred at the same time that the amount of fuel consumed to generate electricity increased by 37 percent since 1990 (EPA, 2007a). While the Acid Rain Program was responsible for a significant portion of the emission reductions, other programs, including the NO_X Budget Trading Program, also contributed to the emission reductions.

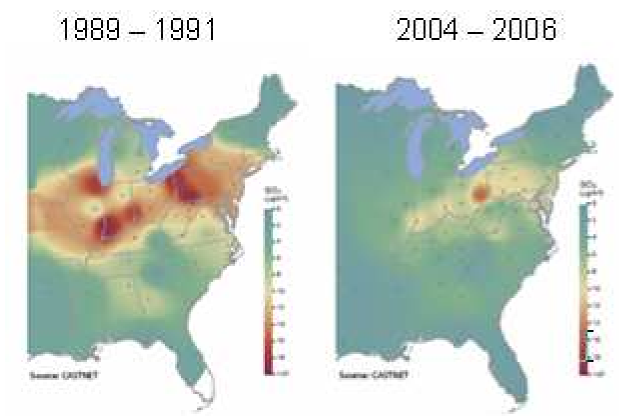
Figure 4.7: Annual NO_X Emissions from Acid Rain Program Emission Sources, 1980-2006



Source: EPA, 2007a

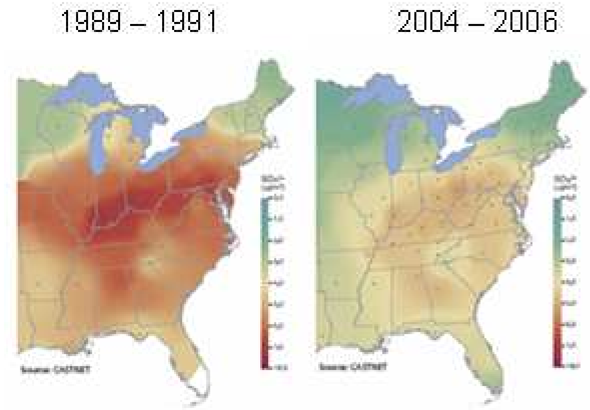
By delivering significant emission reductions, the Acid Rain Program has contributed to several environmental improvements, including localized air quality improvements and reduced risks to natural resources and human health. Air quality data collected by various local, state, and national air monitoring stations across the US have shown far-reaching improvements. Between 1990 and 2006, national average SO_2 ambient concentrations decreased 48 percent (see Figure 4.8). Furthermore, sulfate concentrations, a major component of fine particulate matter and regional haze, have decreased by as much as 37 percent in the Eastern US compared to 1990 levels (see Figure 4.9). Since 1989, both wet and dry deposition have decreased by 28 and 35 percent, respectively, in the northeast and mid-Atlantic regions (see Figure 4.10). As a result, some acidified water resources in these regions have started to recover. Recent studies show improvements in acidity (as measured by sulfates and nitrates) and aluminum concentrations, both of which contribute to loss of fish and other aquatic species. Acid neutralizing capacity is also increasing in some areas (see Figure 4.11).

Figure 4.8: Eastern US Annual Average SO_2 Concentration, 1989-1991 and 2004-2006



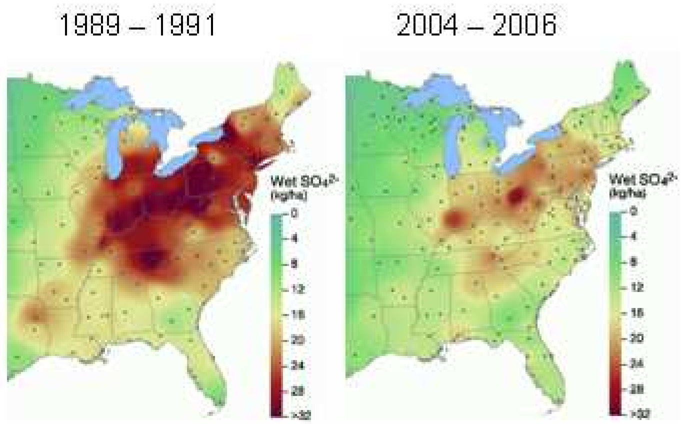
Source: EPA, 2007a

Figure 4.9: Eastern US Annual Average Ambient Sulfate Concentration, 1989-1991 and 2004-2006



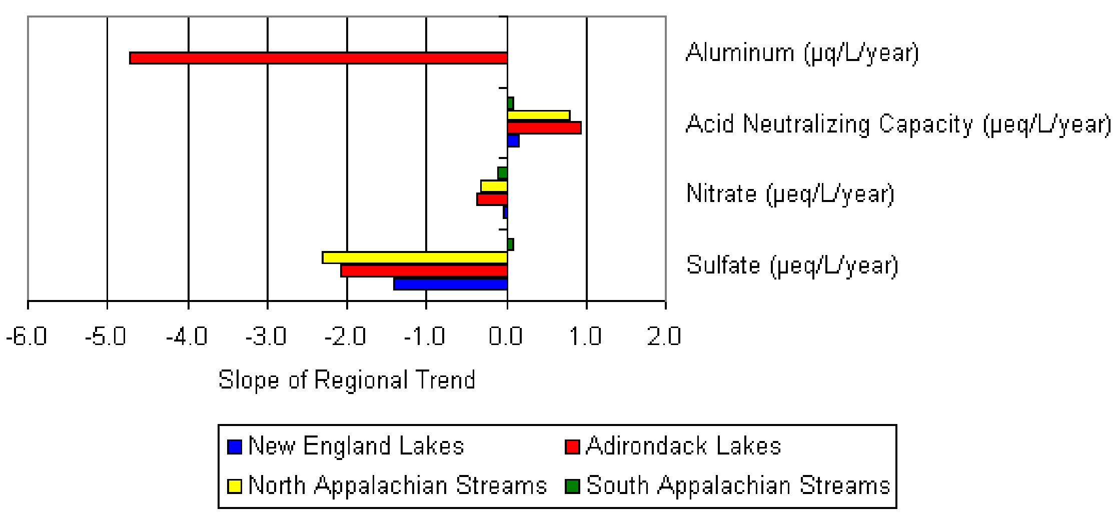
Source: EPA, 2007a

Figure 4.10: Eastern US Annual Average Wet Sulfate Deposition, 1989-1991 and 2004-2006



Source: EPA, 2007a

Figure 4.11: Regional Trends in Lakes and Streams, 1990-2005

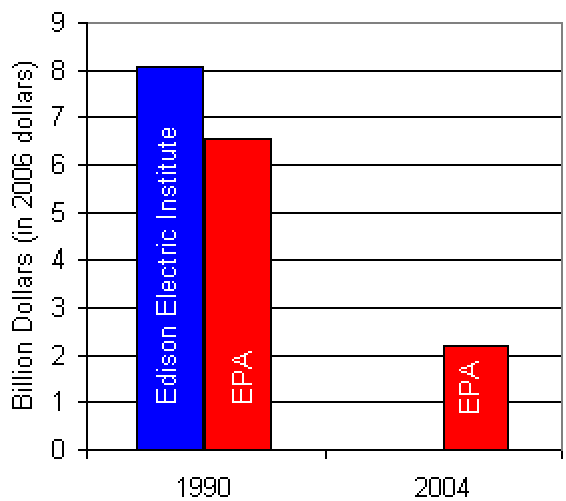


Source: EPA, 2007a

Another key result is the cost to implement the Acid Rain Program. Emission reductions and resulting human health and environmental benefits of the Acid Rain Program were achieved at a fraction of the expected cost (see Figure 4.12). At the time of the Acid Rain Program's enactment, the Edison Electric Institute, an industry think tank, and EPA estimated the costs of compliance at more than $6 billion per year. However, because of factors influenced by both the Acid Rain Program and exogenous factors, the estimated costs of compliance in 2010 have fallen dramatically. More recent estimates put the cost at just over $2 billion annually to comply with the SO_2 provisions of the Acid Rain Program. This is corroborated by independent studies conducted by research organizations (Carlson et al., 2000).

A recent study estimates that the annual environmental and human health benefits of the Acid Rain Program exceed $142 billion. In contrast, annual compliance costs total $3.5 billion – $2.3 billion for the SO_2 program and $1.2 billion for the NO_X program (Chestnut and Mills, 2005).[20] This is a benefit-to-cost ratio of more than 40 to one.

Figure 4.12: Projected Annual Costs for the SO_2 Acid Rain Program in 2010



Source: Napolitano, 2006

The low compliance costs are due in part to the flexibility provided to emission sources to develop custom compliance strategies and the ability to trade allowances. Emission sources are able to select the most cost-effective means to control emissions from a variety of options, ranging from installing emission control technology and switching fuels to purchasing additional allowances from the trading market. This flexibility has also facilitated innovation and competition among different compliance options. The search for lower cost options to reduce emissions led to experimentation, which improved the understanding and widespread use of nontraditional compliance efforts, such as fuel blending. Traditional FGD technologies had to compete against these options. This competition, coupled with boiler adaptations and flexibility in the operation of FGD equipment, led to technology advances that increased the removal effectiveness of FGD equipment. Removal rates have increased from 90 to 95 percent, with recent measurements reporting 98 percent removal of SO_2. These innovations reduced the capital costs of the equipment by approximately 50 percent (Napolitano et al, 2007a).

[20] Values for benefits and costs are expressed in 2006 dollars.

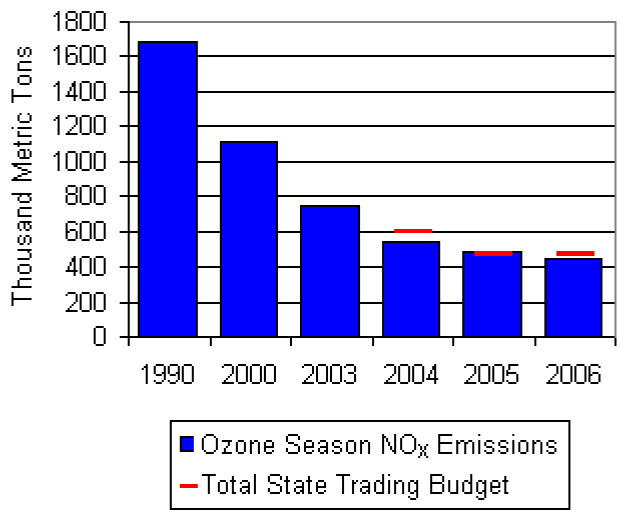
Trading has also lowered the overall cost of compliance. Given the option to trade, emission sources that face higher costs of abatement may choose to purchase some or all of their necessary allowances from the trading market. Alternatively, emission sources that face lower abatement costs may choose to reduce emissions beyond their allocation and sell the surplus allowances in the trading market. Through this process, market forces drive down the cost of reducing the next ton of emissions, resulting in lower allowance prices and overall costs for reducing emissions.

Another factor contributing to the success of the Acid Rain Program is the high level of compliance. Compliance with the key program requirements averages over 99 percent each year due to the fact that the program was designed to create the proper incentives for complete and accurate emission data and full compliance (Napolitano et al., 2007a). In 2005 and 2006, 100 percent of the approximately 3,500 emission sources of the Acid Rain program were in compliance with the allowance holding requirements for SO_2 emissions (EPA, 2006d; EPA, 2007a).

NO_X Budget Trading Program Results

The NO_X Budget Trading Program has successfully reduced ozone season NO_X emissions throughout the affected region. In 2006, ozone season NO_X emissions in the NO_X Budget Trading Program states were 74 percent lower than 1990 emissions and 60 percent lower than 2000 emissions (see Figure 4.13).

Figure 4.13: Ozone Season NO_X Emissions in the NO_X Budget Trading Program Region, 1990-2006



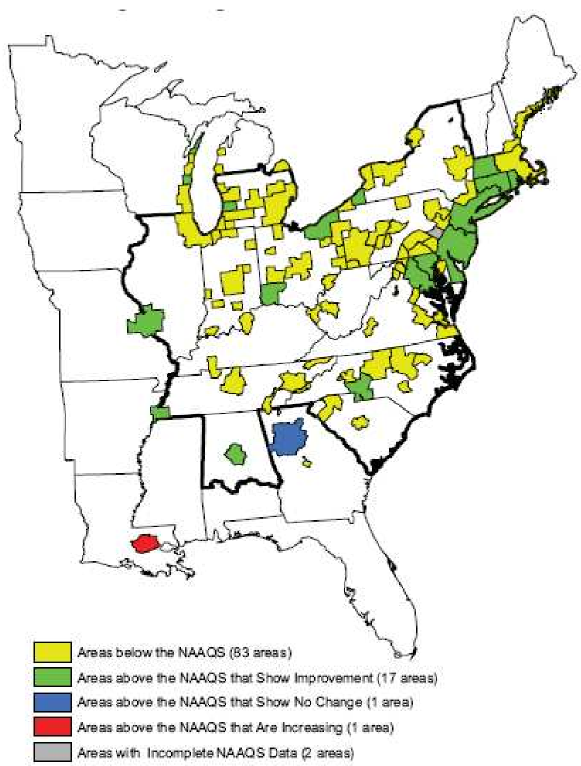
Source: EPA, 2007d

Many of the NO_X reductions since 1990 are a result of other programs implemented under the CAA, such as the Acid Rain Program and other state-, local-, and national-level programs. The significant reductions from 2000 to 2003 were largely due to an earlier NO_X cap and trade program that operated between 1999 and 2002 in 11 Eastern states and the District of Columbia. The NO_X Budget Trading program, which began for select states in 2003 and additional states in 2004,[21] is responsible for many of the emissions reductions from 2003 forward.

These emission reductions have led to improvements in ambient concentrations of ground-level ozone since the implementation of the NO_X Budget Trading Program in 2003. Actual reductions in ozone levels ranged from five to eight percent (EPA, 2007d). Of the 104 areas in the Eastern US that were designated as 8-hour ozone NAAQS nonattainment areas in 2004, all but two areas had improved ozone air quality (see Figure 4.14). Furthermore, by 2006, 80 percent of the areas (83 areas) in the East now have air quality that attains the ozone NAAQS (EPA, 2007d).

As with the Acid Rain Program, compliance with the two critical elements of the NO_X Budget Trading Program – emission measurement, reporting, and allowance holding requirements – is very high, currently over 99 percent. Out of 2,579 affected emission sources in 2006, only four facilities with seven units were out of compliance with the allowance holding requirement of the NO_X Budget Trading Program (EPA, 2007d). Compliance results in previous years were similar to the 2006 results.

Figure 4.14: Changes in 8-Hour Ozone NAAQS Nonattainment, 2001-2003 and 2004-2006



Source: EPA, 2007d

The Acid Rain Program and NO_X Budget Trading Program will form the foundation for the CAIR and CAVR cap and trade programs. These new rules were designed to address the interstate transport of ozone, fine particulate, and toxic pollution that contribute to poor air quality and regional haze. All three programs were promulgated by EPA without specific legislation establishing the framework for the programs. EPA and

[21] One state, Missouri, did not participate in the NO_X Budget Trading Program until the 2007 ozone season.

the Administration pursued legislation, titled Clear Skies, but failed to win approval in Congress. Having clear authority for the new cap and trade programs through legislation could have reduced the complexity and legal challenges associated with CAIR and CAVR. However, EPA was able to use existing authority to successfully promulgate the new package of rules.

Design Elements of the US Cap and Trade Programs

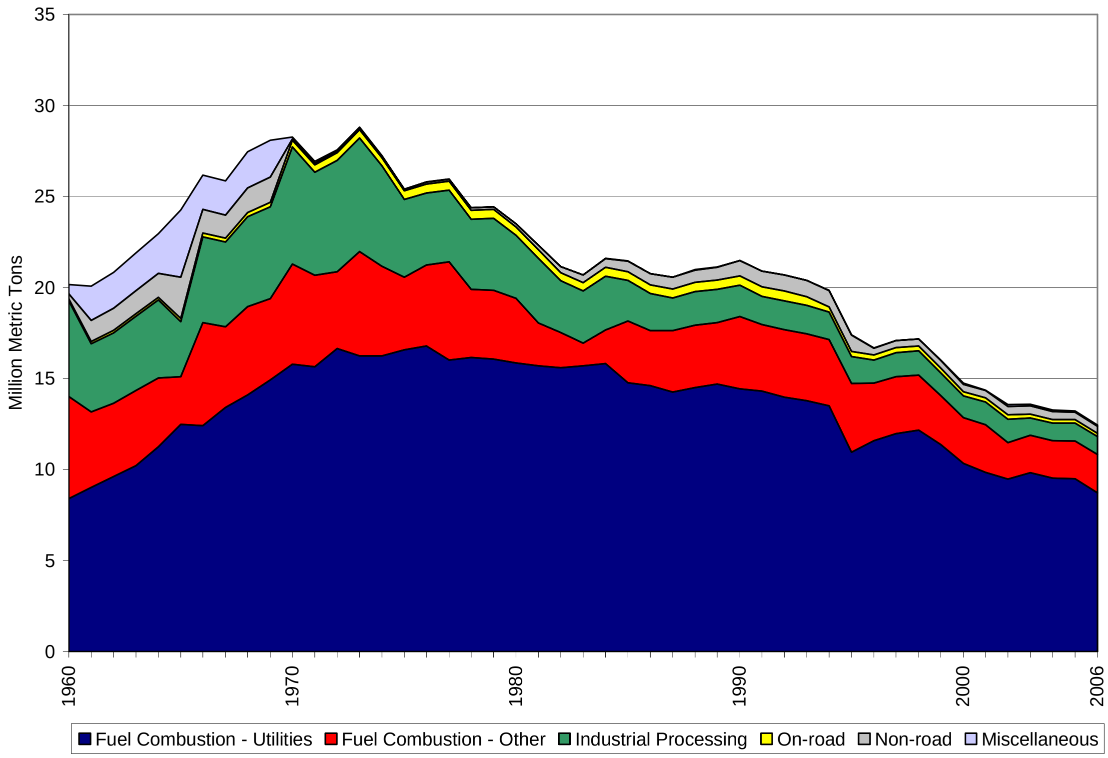
The Acid Rain Program was a new approach to emissions control that gave emission sources the flexibility to develop their own compliance strategies while requiring strict accountability for every ton of emissions. This new approach required significant and careful thought about how to structure new design elements which had not existed in previous programs. The key design elements of the Acid Rain Program include:

- Applicability – which emission sources are required to participate in the program.
- Emission cap – the sum of emissions authorized by the total number of emission allowances. The cap establishes the emission limit on total emissions from affected emission sources.
- Allowance distribution – how the allowances are distributed, or allocated, to each emission source.
- Allowance rules – provisions that define an allowance, specify how allowances can be used for compliance, and specify treatment of surplus allowances.
- Data collection and management – systems to manage information about allowance transactions and holdings and systems to collect, quality assure, and manage emissions and monitoring data.
- Emission measurement and reporting – protocols to measure, report, and verify emissions. Complete, accurate, and consistent emission measurement is critical to the operation and environmental integrity of the program; it is the indicator used to assess compliance.
- Enforcement and compliance assistance – compliance requirements, penalties for non-compliance, and enforcement procedures and institutions. Strict and consistent enforcement is essential to the success and credibility of the program. Ensuring that the regulated community understands the requirements and stays abreast of its emission situation is also critical.
- Assessment – monitoring networks and analytical tools to assess whether the cap and trade program is having the desired environmental and air quality effects.

Applicability

The cap and trade approach of the Acid Rain Program focuses on SO_2 emissions from the electric power sector, specifically, electricity generators that burn fossil fuels (i.e., coal, oil, or natural gas). When the 1990 CAA Amendments were approved, the electric power sector emitted approximately two-thirds of the nationwide SO_2 emissions (see Figure 4.15). The power sector was also responsible for a significant amount of total NO_X emissions and, from an administrative standpoint, the sector was relatively easy to regulate because the number of sources was manageable (about 2,000 sources at the time the program was developed). Furthermore, emissions were easily monitored, emission control technologies were commercially available, opportunities to shift production outside the regulated region (i.e., leakage) were limited, and EPA had significant experience regulating this sector.

Figure 4.15: US SO_2 Emission Trends by Emission Category, 1960-2006



Source: EPA, 2007c

Emission Cap

Because of the importance of the cap in both establishing the environmental goal and in determining the compliance cost for emission sources, policymakers and other stakeholders responsible for designing the Acid Rain Program spent considerable time deliberating about the level of the cap.

Scientific studies at the time predicted that the program's primary objectives – reducing emissions to mitigate acid deposition problems in the Eastern US – might be attained by reducing nationwide annual emissions between 7.3 million and 10.9 million metric tons below the 1980 level. The ultimate goal, a 9.1 million metric ton reduction from all sectors, including a 7.7 million metric ton reduction from the power sector, was established as a long-term target for the year 2010. The long-term target provided power plant owners and operators with certainty about future emission reduction requirements and a sufficient time horizon to develop compliance strategies to minimize costs.

Allowance Distribution

The level of the emission cap determines the number of allowances that are distributed to emission sources. The method for distributing these allowances, however, can vary from program to program. The allowances for the Acid Rain Program are distributed according to formulas that reflect historical fuel use and specified emission rates. For Phase I (1995-1999) of the program, the general allocation formula was based on an emission source's average annual heat input (in million Btu) in the years 1985 to 1987. The allocation was calculated by multiplying the average heat input by 1.1 kilograms (2.5 pounds) of SO_2 per million Btu of heat input. In Phase II (beginning in

2000) of the program, the allocation formula was lowered to 0.55 kilograms (1.2 pounds) per million Btu of heat input. Allowances in the Acid Rain Program are distributed to emission sources in perpetuity at no cost. Some of the more recent cap and trade programs, such as the NO_X Budget Trading Program, include optional updating provisions that require the state government to periodically recalculate the allowance allocations.

Regardless of the frequency and method of allowance allocations, it is important to provide power plant owners and operators with certainty about allocations so they may develop compliance strategies that minimize costs. Providing certainty requires that allowances be allocated or sold in advance of the program's start date and emission sources be provided with several years of allowances in advance. In addition, allowance holders must have confidence that the government will treat allowances *similar* to a property right (i.e., the allowance holders should have reasonable certainty that allowances will not be withdrawn without transparent, pre-defined procedures). Certainty is essential if a cap and trade program is to achieve its potential cost-effectiveness and environmental-effectiveness.

Allowance Rules

One allowance represents the legal authorization to emit a specific amount of emissions (e.g., one short ton). At the end of the calendar year, emission sources must surrender sufficient allowances for every short ton of SO_2 emitted. If an emission source's annual emissions are below the allowance holdings, the emission source can save, or bank, the surplus emissions for use in the future. The option to bank surplus allowances provides emission sources with temporal flexibility and creates an incentive for emission sources to reduce emissions more than required in order to bank allowances that can be used in the future when emission reductions may be more difficult or expensive.

EPA does not place restrictions on allowance trades and does not interfere with private transactions (e.g., mandating or restricting transactions between firms). Emission sources are free to enter into transactions with any other market participant. Minimizing restrictions on the market for allowances helps minimize complexity, increase liquidity, and reduce overall compliance costs.

Emission Measurement and Reporting

The Acid Rain Program includes provisions that promote accurate and consistent monitoring, reporting, and verification. All affected emission sources are required to measure and record SO_2, NO_X, and CO_2 emissions using continuous emission monitoring systems (CEMS) or, for emission sources not burning coal, an approved alternative measurement method. The vast majority of emissions are monitored with CEMS while the alternatives provide an efficient means of monitoring emissions from the large universe of units with lower overall mass emissions. Table 4.4 shows the number of units with and without CEMS for SO_2 as well as the amount of SO_2 emissions monitored using CEMS.

Table 4.4: SO_2 Monitoring Methodology, 2006

	Number of Emission Sources	Percent of Total Emissions
Coal with CEMS	1,063	98.41%
Other fuels with CEMS	67	0.40%
Other fuels without CEMS	2,330	1.19%

Source: EPA, 2007a

CEMS and approved alternatives are a cornerstone of the Acid Rain Program's accountability and transparency. Since the program's inception in 1995, affected sources have reported hourly emission data and supplemental data (e.g., operating hours, heat input, equipment calibration and test results) to EPA in quarterly electronic reports. Using automated software audits, EPA rigorously checks the completeness, quality, and integrity of these data. EPA also publishes all emission data via the Internet.

The emission data must be consistent and complete because it is used to determine compliance with the allowance holding requirements. Therefore, enforcement of the US Acid Rain Program relies on strong quality assurance and quality control to assure data quality and promote self-enforcement. The EPA provides emission sources with software tools that allow them to routinely check their electronic reporting equipment and calculations before submitting this data to the EPA for annual reconciliation. Additionally, the EPA conducts electronic audits based on statistical criteria drawn from past emission reports and field audits (Schakenbach et al., 2006). EPA and state environment agencies also conduct field audits to ensure that emission monitoring equipment is operated and maintained according to the approved power plant's monitoring plan, verify that the power plant is keeping records to support the emission measurements and the monitor's performance, and that all calibrations and checks are properly conducted.

While the program strives for 100 percent data availability and accuracy of emission monitoring equipment, monitor availability averages slightly more than 98 percent. To address this discrepancy, the monitoring and reporting requirements include data substitution provisions that provide for automatic generation of substitute data by a data handling and acquisition system. The substitute data requirements become increasingly conservative (i.e., punitive) as the monitor's availability or failure to measure valid data increases. The punitive nature of the substitute data requirements ensures not only that sources do not underreport emissions, but also serves as an incentive to monitor properly and avoid the use of substitute data. This provision has proven very effective as a strong incentive for sources to strive for complete quality assured data.

The combination of strong data quality assurance and quality control, electronic and onsite auditing, and automatic and increasingly punitive data substitution provides the foundation for an easily enforceable program that delivers credible emission reductions.

Enforcement and Compliance Assistance

Determining compliance with the allowance holding requirements of the Acid Rain Program and NO_X Budget Trading Program is a simple mathematical check. At the end of the compliance period, the EPA compares each emission source's annual SO_2 or NO_X emission data against the source's SO_2 or NO_X allowance holdings to ensure that the emission source has the appropriate number of allowances to compensate for emissions.

When emissions exceed the number of allowances for the Acid Rain Program, the emission source must pay an automatic penalty of $3,152 per excess short ton and forfeit one future allowance for each excess ton. If an emission source exceeds the number of allowances in the NO_X Budget Trading Program, the source must surrender three future allowances to the EPA. One of the allowances offsets the excess ton of emissions and other two allowances are a penalty for non-compliance. Given the range of allowance prices in recent years, the penalty is equivalent to about $1,500 to $4,000 per excess ton. These penalties are automatic; environmental regulators do not have discretion to negotiate the penalties with the non-compliant emission source. This reduces delays due to protracted discussions and litigation and guarantees specific and stringent consequences for noncompliance.

While the EPA is committed to strict enforcement of the Acid Rain Program and NO_X Budget Trading Program, EPA also makes an effort to help affected emission sources stay in compliance by providing compliance assistance. This includes holding workshops on the technical aspects of the program, such as monitoring and reporting requirements, and working with sources one-on-one to help them understand the program's requirements as well as assisting with issues that could lead to non-compliance. EPA has a team of staff assigned to specific regions of the country. This team is available to answer questions about the program's various requirements, especially monitoring and reporting. This effort has contributed to remarkably high compliance rates averaging over 99 percent since the start of the program.

Assessment

Periodically assessing progress toward environmental, human health, and air quality goals is a critical element of sound air quality management. It is also important to look for any intended or unintended consequences or disbenefits of an emission control program.

EPA regularly assesses the Acid Rain Program and NO_X Budget Trading Program to ensure that the emission reductions lead to the desired environmental and human health benefits. EPA, in conjunction with state and local authorities and other government agencies, has established an extensive network of monitors to measure ambient air quality in urban and rural areas, acid deposition (wet and dry), and surface water chemistry. The data from these monitoring networks, emission data from sources, scientific studies, and modeling studies are used to assess the programs' progress toward achieving their environmental goals.

EPA and independent experts also periodically assess the cost-effectiveness of the Acid Rain Program and NO_X Budget Program through benefit-cost analyses. A 2005 analysis of the Acid Rain Program found that the benefits of the program exceeded the costs by a ratio of more than 40 to one (Chestnut and Mills, 2005). This particular study integrated recent data from the monitoring networks with updated scientific information. A broader set of impacts which were previously not well understood increased the program's net benefits while newer, unanticipated implementation strategies have lowered estimated costs (EPA, 2006d).

Principles for US Cap and Trade Programs

The design of the Acid Rain Program did not take place through one legislative session. The process of designing the program took years of collaboration between multiple agencies and organizations and relied on scientific, engineering, and economic studies. The design phase also engaged participation from all levels of government, ranging from local agencies to the US Congress. With the legislation in place, the EPA continued to work on program design through the rulemaking process and engaged partners from all stakeholder groups, including industry, state agencies, public interest groups (e.g., non-governmental organizations) and academia. This ensured that the program and associated rules would ultimately yield results at a minimum cost of compliance.

Based on the US experience, EPA has identified five key principles behind a successful cap and trade program. These principles are essential for creating laws and rules that work effectively within the market-based framework. Thus, by understanding and adhering to the principles of simplicity, accountability, proper incentives, transparency, predictability, and consistency, the Acid Rain Program has been designed to promote both compliance and market efficiency.

Simplicity

In order for a cap and trade program to be successful, the program and its rules and obligations should be easily understood by all participants. Overly complex and burdensome rules often result in substantial costs and time investments for both sources and regulating authorities. Certain features of cap and trade programs help to ensure their simplicity. The emissions cap, for example, sets a firm, inviolate limit on emissions. As long as the number of allowances equals the cap and sources do not emit more than they are allowed, the emission reduction goal will be achieved. Rules for allowance trading should be clear and simple, and not include unnecessary restrictions or government interference. The penalty provisions should also be simple, automatic, and provide the appropriate incentives for emission sources to comply with program requirements.

Accountability

A cap and trade program should create a framework that holds both emission sources and the regulating authority accountable. For sources, the program should include elements of oversight and enforcement that ensure compliance and hold them individually responsible for their emissions. Under the Acid Rain Program, emission sources are required to monitor emissions continuously and report emission data on a regular basis. EPA itself is also held accountable through periodic assessments which evaluate the outcomes of the program and ensure its ability to achieve the environmental objective.

Proper Incentives

Any form of environmental policy should create the proper incentives for complete and consistent compliance. The strongest incentive provided by cap and trade programs is the economic value of allowances. This economic certainty gives sources the incentive to lower emissions more than required for compliance in order to bank or sell surplus allowances.

Additionally, the Acid Rain Program was designed to create incentives for sources to install and properly maintain emission measurement equipment. If measurement technologies were not available (e.g., under maintenance), substitute data provisions were used to fill data gaps and replace incorrect emission estimates. The more frequent the measurement technology is not available or not working properly, the more punitive the substitute data provisions. Since the substitute data provisions tend to overestimate emissions, the emission source will have to surrender more allowances to the EPA at the end of the compliance period. Because these allowances have an economic value, this creates a strong financial incentive for emission sources to ensure that their measurement technologies are working properly.

The penalty provisions also create a strong incentive for sources to comply with the program requirements. At the end of each compliance period, if an emission source is out of compliance (i.e., the source does not possess sufficient allowances to compensate for total emissions) the EPA levies a financial penalty in excess of the cost of compliance *and* deducts future allowances from the emission source to ensure that the environmental objective of the program is still met. In 2006, the financial penalty for SO_2 emissions was about six times greater than the market price for allowances.

Finally, the banking provision also provides incentives. For emission sources, the allowance bank acts as insurance against adverse conditions caused by fuel markets, changes in the emission cap, or their own compliance activities by allowing emission sources to save unused allowances for the future. This encourages emission sources to reduce emissions more than required because surplus reductions can be saved for future use.

Predictability and Consistency

Predictability and consistency in the design and application of program rules are important principles for effective cap and trade programs. Together, they help create the right circumstances to encourage innovation and lower costs. With a cap and trade program, emission sources have an incentive to find better and lower-cost opportunities to reduce emissions. This incentive depends upon long-term, predictable, and consistent rules that affect the economic value of emission reductions. This arrangement does not mean, however, that rules cannot change in response to new information. Rather, it means that the framework must include the possibility for change along with an explanation of the process for adjusting the rules while also having defined short- and intermediate-term goals for the next five to 15 years.

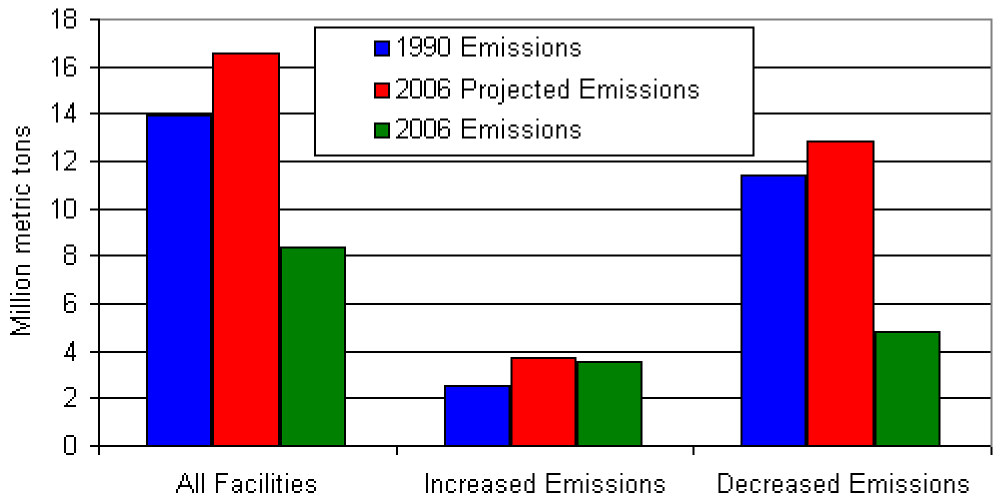
Challenges of the Cap and Trade Approach

The Acid Rain Program and NO_X Budget Trading Program have achieved substantial emission reductions at a cost much lower than a traditional technology- or performance-standard program. As with traditional control programs, cap and trade programs have issues and challenges that must be addressed. These issues and challenges include the spatial distribution of emissions, options to revise the emissions cap, potential consequences of allowance banking, equity in allowance allocations, and emission measurement, verification, and reporting.

Spatial Distribution of Emissions

A major reservation often expressed about a cap and trade approach is that it may produce "hotspots" – areas of high pollution concentrations due to increased emissions from emission sources that purchased allowances. Unlike more traditional regulation that may address regional and seasonal issues by tightening technology or performance standards where or when environmental problems are more critical, the theoretical design of cap and trade programs allow trading across regions and banking of emission allowances without regard to the possible environmental consequences. After extensive review of the Acid Rain Program, EPA and independent analyses indicate that emission hotspots have not occurred (EPA, 2005; Kinner and Birnbaum, 2004; Swift, 2000; and Burtraw and Palmer, 2003). Interestingly, regions with the highest emissions, such as the north-central region, have had the largest reductions (see Figure 4.6). This occurred at both the regional level and near individual electric power plants. Perhaps more importantly, monitoring data in areas where emissions increased slightly suggest that air quality in those areas still improved due to a large overall reduction in regionally-transported air pollution as a result of the Acid Rain Program (EPA, 2005). And finally, emission sources that saw slight increases in total emissions reduced their emission intensity (emissions/unit of heat input) (see Figure 4.16).

Figure 4.16: Comparison of Emissions from Sources that Reduced Emissions and Sources that Increased Emissions



Source: Kinner & Birnbaum, 2004

Academic and government analysts have pointed out it is unlikely that any given area will have negative impacts from the Acid Rain Program, NO_X Budget Trading Program, or CAIR because the cap is set low enough that it requires emission reductions by a large percentage of sources. In addition, local air quality programs can lock in emission reductions where states and local governments believe they are necessary. Allowances from EPA's trading programs cannot be used to avoid meeting emission control requirements intended to protect local air quality.

Options to Revise the Emissions Cap

The concept of a cap – a limit on total emissions, not just emission rates – was a key innovation of the cap and trade programs. The Acid Rain Program, however, does not include provisions for reassessing the emission cap and, if necessary, revising the cap level. New information from scientific studies, ecological assessments, and health observations may necessitate lower emission caps to adequately protect human health and the environment. Learning from the lesson of the Acid Rain Program, the NO_X Budget Trading Program includes a provision for revising the cap in the face of new evidence that lower emission levels are necessary. EPA exercised that authority to lower the NO_X cap for CAIR.

Cap and trade programs, to the extent revisions to the cap are authorized by law, could adjust to new information by changing the level of the cap through a transparent, pre-defined process. However, if the level of the cap is changed, it will be important to provide emission sources with sufficient notice, and to establish a credible process for lowering the cap and an equitable process for the treatment of existing allowance holdings. For example, the CAIR program does not eliminate the surplus allowances that emission sources have banked because they reduced SO_2 and NO_X emissions greater than necessary under the Acid Rain Program and NO_X Budget Trading Program.

Potential Consequences of Allowance Banking

Another reservation sometimes expressed about cap and trade programs is the potential of banked allowances to permit temporary increases in emissions, thereby hindering the ability to achieve the environmental goal. Allowance banking provides a number of benefits, including temporal flexibility for managers of emission sources, stability in the trading market for allowances, and incentives to make early emission reductions in excess of what is required. However, since emission sources can save the surplus allowances for use in the future, banking can delay the achievement of the ultimate emission reduction goal. In US cap and trade programs, the US Congress and EPA decided that the trade off between the benefits of banking, including early reductions, and delaying the future emission reduction goal are worthwhile. Notably, when EPA developed CAIR, the implications of banked ARP SO_2 and NO_X allowances were accounted for as a way to provide a smooth, gradual transition to the significantly lower CAIR emission caps. Already, the ability to bank Acid Rain Program allowances for use in CAIR is leading to early emission reductions for SO_2 and greater health protection for the public. EPA also considered whether to adopt the NO_X Budget Trading Program's "flow control" mechanism in CAIR. The "flow control" is meant to limit the possible episodic consequences of banking. However, EPA found that the "flow control" only created confusion, uncertainty, and additional burden with little benefit. Therefore, "flow control" was not included in CAIR.

Equity in Allowance Allocations

Most academics that study the theory of cap and trade promote auctions as the most efficient approach to allocate allowances because it internalizes the cost of the resource – air quality – and ensures that pricing the resource leads to the most efficient use of the resource. Academics not only see the auction of allowances as way to achieve a desired result, but also as a way to generate revenue and to lower other distortionary taxes (e.g., labor) in the US. For political reasons, however, auctions are often not feasible so the majority of allowances are distributed to emission sources through no-cost allocations. While the allocation process does not have an effect on the environmental outcome of the program – the cap establishes the non-violate environmental goal – the allocation methodology can have economic and political consequences.

Different allocation methodologies can reward different behaviors and create "winners" and "losers" among emission sources. Because the allowances have economic value, owners and operators of emission sources may lobby for specific methodologies that maximize their allocation. But because the cap is fixed, increasing the number of allowances to any one emission source means there are fewer remaining allowances to divide among the other sources.

In the Acid Rain Program, allocations are based on historical heat input, not historical emissions, so emission sources that have already implemented approaches to reduce emissions (e.g., installation of FGD equipment or use of low-sulfur fuels) are not penalized for adopting early strategies to reduce emissions. Likewise, emission sources that have not taken action to reduce emissions are not rewarded for their inaction. Allocations based on electricity generation or output would, in theory, yield similar results.

Emission Measurement, Verification, and Reporting

Because compliance is based on total emissions and the value of allowances is based, in part, on the credibility of the program, consistent, accurate, and complete emission monitoring is essential to the success of a cap and trade program. If emission sources cannot accurately measure the pollutant(s) emitted, cap and trade, or any form of emission trading program, may not be the appropriate policy tool to attain significant emission reductions. It is worth noting that the inability to monitor emissions effectively is generally a problem for all types of control programs and should be resolved as soon as possible. Accurate monitoring data is more critical in market-based policies such as emission taxes and cap and trade. In cap and trade programs, emission sources must surrender sufficient allowances to offset reported emissions. Because the allowances have a value, if a program is not strongly enforced and emission measurements are not properly verified, emission sources have an incentive to underreport emissions so that they can reduce the number of allowances required for compliance and sell surplus allowances to other emission sources. This not only undermines achievement of the emission cap, it also lowers the value of allowances because the underreporting of emissions increases the supply of allowances.

Lessons Learned from the Acid Rain Program and NO_X Budget Trading Program

As seen in the Acid Rain Program and NO_X Budget Trading Program, cap and trade works. Setting strict rules for accountability and giving emission sources the flexibility to develop custom strategies to reduce emissions yields environmental results at significantly lower cost. The US programs demonstrate that cap and trade can work for addressing national or regional air quality problems, for controlling emissions from the electric power sector and large industrial emission sources; and for addressing annual or seasonal pollution problems. While cap and trade is a very flexible tool, it is not appropriate for all air quality challenges. Local problems often require local control programs due to the nature of the emitters (e.g., mobile sources), proportion of the problem from a small number of major facilities, and other factors . However, the US experience has shown that a hybrid system of local controls to protect local air quality and cap and trade programs to achieve broad, regional reductions can complement one another and lead to improvements in local air quality.

There are several important design and implementation lessons from EPA's 18 years of experience designing and implementing cap and trade programs. The key lessons are discussed below.

Design Lessons

<u>Partnerships and Dialogue</u>

During the design phase, the US Acid Rain Program and other US cap and trade programs have benefited significantly from partnerships and dialogue with stakeholders. By providing the EPA, policymakers, industry, and NGOs with the opportunity to develop a better understanding of the goals, problems, and realities faced by the different players, these partnerships and dialogues resulted in significant time and cost savings. Perhaps the best example of this emerged from the success of the Acid Rain Advisory Committee (ARAC), forged immediately after the passage of the 1990 amendments to the CAA. This group – composed of 44 individuals representing industry, NGOs, state agencies, and academia – was created to advise the EPA on the design of rules to implement the

US Acid Rain Program (McLean, 1995). From the beginning of the process, the members of ARAC became actively engaged in the rulemaking process and acted as a “sounding board” for the EPA as it considered various regulatory options. With the help of the committee, the EPA identified potential problems and developed solutions early on. Furthermore, because ARAC members were invested in the Acid Rain Program and therefore committed to its success, committee participants publicly promoted the program and voluntarily educated others within their stakeholder groups.

Drawing from past experience with ARAC, the EPA has conducted ongoing dialogues with Acid Rain Program stakeholders on a range of topics, from monitoring and permitting to allowance trading and data system development. Additionally, policymakers and EPA have applied this lesson learned to the other US cap and trade programs, engaging stakeholders in early and often discussion and collaboration.

A similar process that developed programmatic expertise and support occurred for the NO_X Budget Trading Program. Before the start of the program, EPA worked with the states in the Ozone Transport Assessment Group (OTAG) to better understand the nature of the ground-level ozone problem and develop cost-effective approaches to address the problem. The members of OTAG included governments from 37 Eastern states, industries that contributed to the ground-level ozone problem, top scientists at US universities, and NGOs. The group not only provided technical support, but it also created political support for the NO_X Budget Trading Program.

Flexibility

A key feature of the Acid Rain Program are the different roles that EPA and emission sources play compared to traditional emission control approaches. In the Acid Rain Program the manager of an emission source, who best understands its operation and business, has the flexibility to develop compliance strategies and make decisions on technologies, fuels, operational practices, and investments. Furthermore, the manager can change its approach, without government review and approval, as better methods become available. Instead, the government is focused on setting the environmental goal. EPA also collects and verifies emission data, tracks allowance transactions, assesses and enforces compliance, and publishes information about the program.

This flexibility and responsibility to develop compliance strategies creates a continuous opportunity for regulated sources to seek customized, cost-effective approaches to control emissions. Emission sources are not forced to install technology that may not be appropriate for their configuration or business plan and the compliance strategies are not subject to complex review by EPA to determine if the decisions meet technical specifications or if pollution control equipment is operating properly. Because EPA does not review the compliance strategies, there is no uncertainty about regulatory approval. The stringency and simplicity of the emission cap ensures that the environmental benefits will be achieved regardless of individual compliance strategies. The result is built-in flexibility that not only keeps costs low for sources that choose cost-effective compliance strategies, but also minimizes the administrative costs of the program.

As part of its compliance strategy a regulated source may engage in allowance trading – buying or selling surplus allowances. Because of the cap, there is no need for EPA to review each transaction, thereby reducing the time, transaction costs, and administrative costs to trade allowances.

Accountability

Accountability is a prerequisite for flexibility – emission sources must be held accountable for accurately measuring and reporting all emissions, and complying with program requirements. This requires both complete and accurate emission measurement and strong, consistent enforcement of program rules and allowance requirements. EPA believes the emission data underlying the Acid Rain Program, including SO_2, NO_X, and CO_2 emissions, is the most accurate and comprehensive emission data collected by EPA or any other government agency. To determine that regulated sources are in compliance, EPA requires monitoring, reporting, and verification of emissions to ensure emission data is complete, consistent, and every ton is accounted for. The quality of emission monitoring plays an important role in determining the market efficiency, investor confidence, and ability to meet the emission reduction target.

Emission data is subjected to extensive, rigorous quality assurance (QA) checks by the regulated sources and EPA to ensure completeness and accuracy. Sources implement a mandatory and comprehensive on-site QA program where monitoring systems are subjected to daily calibration and a series of checks and tests, before certification and submission of their quarterly electronic data reports to EPA. EPA audits the reported data through a multi-step process, and supplements this audit process with separate ad hoc analyses and data cleanup surveys (Schakenbach et al., 2006). Additionally, EPA offers this audit software to emission sources and states to facilitate the reporting of consistent and accurate emission data. High-quality emission data provides the basis for ensuring compliance and assessing achievement of the emission reduction goal and contributes to the credibility of the allowance market.

Simplicity and Clarity

Clear, simple rules are easier and less costly to implement. Complexity may be required in some cases, but it should be minimized whenever possible. The Acid Rain Program has demonstrated that operating the program with simple, clear goals and rules saves time and money for both emission sources and EPA. Moreover, the high compliance rate with the critical elements of the SO_2 and NO_X programs – greater than 99 percent – is due in large part to rules that are clear and easily enforced. In contrast, complexity often requires more decisions, debate, and information collection. Such a situation can create uncertainty and unnecessary burden that may lead to delays, opportunities foregone, and, ultimately, higher costs.

While simplicity was a key objective of the Acid Rain Program, some areas of the program included unnecessary complexity. Some of these complexities were introduced in the political process as a way to gain support for the program. Two aspects of the program – allocation formulas and partial coverage of the electricity sector during Phase I – had the potential to increase uncertainty, program costs, and administrative burden, and may have benefited from greater simplicity.

Because Phase I of the Acid Rain Program covered only a subset of electricity generating units, there was a possibility of “leakage” – shifting generation from a Phase I electric power plant to an electric power plant not required to participate in the program until Phase II. The electric power sector is interconnected, meaning sources could easily shift generation from one combustion unit to another. To address the possibility of “leakage”, the program includes a reduced utilization provision that requires Phase I electric power plants that reduce utilization to demonstrate that the reduction was not offset by an increase at a non-Phase I electric power plant. If the Acid Rain Program had included all regulated sources in Phase I, there would have been no possibility of leakage and the complicated reduced utilization provision would not have been necessary.

Legislation

The Acid Rain Program benefited from good legislation. Environmental goals were set and established through a phased-in emission reduction approach. There were few legal challenges to the rules EPA issued and none of the challenges delayed implementation of the cap and trade program. What little litigation did occur revolved around interpretations of statutory provisions that, in some instances, were overly complex or unclear.

In most cases the legislation provided clear, easy-to-understand, and easy-to-implement language. For instance, the allocations for the first phase of the SO_2 program were printed in the law, leaving no question about the approach or results. To ensure that the level of the cap was maintained through the allocation for the second phase, the legislation included a “ratchet” provision that required EPA to reduce each emission source’s allocation pro-rata if the various allocation formulas resulted in allocations greater than the cap. The law also made it clear that if the rules were delayed, every source would have to meet a source-specific emission limit without the flexibility of trading. This created the likelihood of very real costs associated with delaying the environmental improvement promised by the legislation.

The NO_X Budget Trading Program did not have the benefit of specific legislation authorizing the program. Instead, the program was promulgated under broad EPA authority. Due to lawsuits from industry and other groups, the judicial court suspended the NO_X Budget Program while they evaluated the program rules. At about the time the program was supposed to start, the court upheld EPA’s regulation, but required that EPA delay the start date of the program by one year. EPA was also required to make some small adjustments in the first year that made the program less effective environmentally. Overall, less environment protection occurred at the beginning of the program, and, ironically, costs were higher because emission sources had to prepare quickly for the new program which raised the costs of installing emission controls.

Adaptability

Air quality management approaches, including cap and trade, need the ability to adapt to new information, practices, or technology. EPA has made a number of changes to the Acid Rain Program and NO_X Budget Trading Program. Most of the changes were intended to streamline the programs; improve the quality of emission data; take advantage of advances in information technology and the Internet; minimize burden and costs for regulated sources, market participants, and EPA; and improve the environmental accountability and results of the program.

Complementary

Cap and trade programs work best on a regional or larger scale. By requiring significant reductions of regional pollution that is often transported across state boundaries, cap and trade programs may also, and often do, improve local air quality (see Figures 4.8, 4.9, and 4.10). However, eliminating high, localized concentrations of emissions is not the primary purpose of cap and trade programs. To protect local air quality, cap and trade programs should complement, not conflict with, state or local programs.

In the cases of the Acid Rain Program and NO_X Budget Trading Program, regulated sources must comply with all applicable local, state, and national emission requirements, regardless of the number of allowances held. This means that local and state governments can impose additional source-specific emission limits as necessary to protect local air quality. The governments may not, however, place restrictions on an emission source's ability to trade allowances with other emission sources or market participants.

Greater Reductions, Lower Cost

EPA found that the costs of complying with the US cap and trade programs were much lower than technology mandates or emission performance standards and had a smaller economic impact on businesses. In the case of the NO_X Budget Trading Program, the lower cost and reduced burden of a cap and trade program on emission sources enabled EPA to require greater NO_X reductions than would be possible with costlier mandates or standards. This provided industry groups a more flexible and less-expensive program and offered state environmental agencies and NGOs greater environmental improvement than otherwise would have been possible.

Under CAIR, EPA was able to pursue larger SO_2 reductions in the Eastern US because the costs of the cap and trade program on a per ton basis of SO_2 reduced were no more expensive than Congress was willing to pay for the original Acid Rain Program. Though the SO_2 reductions under CAIR are substantial, industry opposition was minimized because the use of cap and trade provides emission sources with compliance flexibility. Furthermore, the experience of the Acid Rain Program has shown that changes in energy prices and capacity loss were minor (see 70 Fed. Reg. 25,162 (May 12, 2005)).

Adaptable Framework

The structure of a cap and trade program can be designed to facilitate changes to adapt to new circumstances and new information on the nature of the air pollution problems. With CAIR, EPA found that it could tighten controls on the power sector for SO_2 and NO_X by reducing the emission cap over time, expanding or contracting controls to be annual or seasonal (covering just the summer months for ozone) or both, and changing the levels of control geographically by setting up a new trading program in the Eastern US that exists within the nationwide Acid Rain Program. Critically important to the approach was the ability to phase in the requirements with plenty of notice for the power sector to make adjustments (see 70 Fed. Reg. 25,162 (May 12, 2005)).

Recognize All Pollutants Are Not Created Equal

When assessing the environmental and human health impacts of the US cap and trade programs, EPA found that, in most parts of the US, each ton of SO_2 reduced generally provides greater benefits than a ton of NO_X reduced. In addition, in the range of control levels that EPA considered, controlling SO_2 emissions is cheaper than controlling NO_X on a per ton basis. This finding substantially influenced control strategies for CAIR and the Clear Skies Initiative.

Baseline Emission Inventories

EPA and states had high quality power sector emission information before the start of the NO_X Budget Trading Program as a result of requirements for continuous monitoring and quarterly emission data reporting under the Acid Rain Program. This was especially true for coal-fired electricity generation which dominates NO_X emissions from the electric power sector. Data for other sectors, such as some industrial emission sources, was not as accurate or robust. As a result, allocations tended to be inflated for the non-electric power sector sources, which in turn were easily able to meet the requirements of the NO_X Budget Trading Program and, in general, became net sellers of the over-allocated allowances (Napolitano et al, 2007a). This points to the importance of having good data when a program is designed to ensure that the control strategy achieves regulatory improvements across the industry it covers. Accurate data is also important for the allocation process and critical if used to set the emission cap.

Phased Cap

When developing the US cap and trade program, EPA recognized that the need to achieve significant reductions quickly had to be balanced with emission sources' ability to install the necessary emission controls in time to meet those requirements. EPA conducts detailed analyses to assess how much time it may take to cost-effectively achieve an emission target. These analyses assess the availability of controls, skilled labor, and materials. EPA considered similar factors in developing the timing and emission reduction requirements for CAIR, with the first phase NO_X and SO_2 reductions required in 2009 and 2010, respectively, and tighter controls in 2015 for both pollutants. While there is currently litigation over CAIR, many companies are acting proactively to install emission controls rather than delaying those installations pending a judicial court decision (Napolitano et al., 2007a).

Air Quality Modeling Reflecting the Reality of Trading

In looking at the emissions reductions and air quality improvements that actually occurred due to the NBP program in 2005, EPA found that the 1998 modeling the Agency did to project emissions from the electric power industry under the NBP and the resulting air quality improvements in ozone concentrations proved right. EPA had analytic tools that could reliably predict the environmental gains from major pollution control strategies across a large region of the country (EPA, 2006e).

No Barriers to Entry

EPA has found that although its air trading programs for the power sector lead to substantial controls going on coal-fired generation units, the trading programs do not pose any significant limitations on the building of new coal-fired generation. Examination of this issue has shown that the real drivers are the relative fuel prices and not the imposition of cap and trade controls. This fact has been corroborated by the Energy Information Administration's recent Annual Energy Outlooks for 2006 and 2007 that have considered CAIR and CAVR controls in place and shown considerable amount of new coal builds (EPA, 2006d).

Implementation Lessons

Emission Monitoring and Reporting

A key factor in the effectiveness of the Acid Rain Program is the production of complete, accurate, and transparent emission data. To achieve this level of data quality, sources must install and operate complex instrumentation, perform frequent calibration procedures, and run data acquisition systems, for which properly trained and dedicated technicians are essential. During the design of these monitoring and reporting requirements, the EPA worked very closely with source representatives to make sure that their needs and constraints were taken into consideration. This strong collaboration resulted in a more practical and easier to implement program, and provided the Agency with additional expertise, which turned out to be fundamental in designing a strong monitoring program.

Compliance Assistance

The goal of the cap and trade programs for both emission sources and EPA is the same – to reduce emissions. EPA's primary means of ensuring this goal is through sound monitoring, reporting, and enforcement that has clear, substantial automatic penalties with the addition of traditional enforcement approaches, if necessary. However, the EPA and state-level staff that work on the Acid Rain Program and NO_X Budget Trading Program also share a goal with the affected emission sources of achieving 100 percent compliance with key program requirements. These staff, where appropriate, work collaboratively with emission sources to ensure that the responsible people at the emission sources clearly understand their obligations (e.g., to monitor and report emissions, address issues as they arise, and hold sufficient allowances to compensate for total emissions). EPA has established a team of several full-time employees dedicated to providing assistance to emissions sources and reviewing the sources' activities throughout the year.

This close working relationship between EPA and the emission sources has led to positive interactions, and strong support for the programs and the role of the regulator. It has also facilitated very high compliance rates exceeding 99 percent. EPA believes that viewing compliance as a joint commitment between the government and emission sources provides credibility to the program and improves the compliance rate.

Assessment

EPA has found considerable value in evaluating the performance of the ARP and NBP programs annually to see that they are doing what we expect them to do. EPA works with other federal agencies and states to run a rural monitoring network that provides annual estimates of SO_2 concentrations, inorganic nitrogen concentrations, sulfate deposition, nitrate deposition, and other important environmental indicators covering acid rain and analyze the results from this set of monitors while also considering the results from EPA and state urban monitoring networks annual reporting on annual average and other measures of SO_2, fine particles and ozone concentrations in metropolitan areas. This information has proven invaluable in showing where the emissions trading programs have been successful and where this has not occurred and more work is needed by EPA and the states to address air pollutants in various parts of the country.

Incentives

By design, cap and trade programs provide incentives for emission sources to develop strategies that reduce the costs of compliance. These incentives need to be clear and strong in order to be effective. In addition, they must account for or replace contradictory incentives created by other programs or rules.

At its most basic level, a cap and trade program must provide disincentives for non-compliance. This requires that the penalty provisions for non-compliance must exceed the cost of compliance (i.e., the penalties must be greater than the cost of reducing emissions to meet the emission source's target.) In the Acid Rain Program, excess emissions trigger clear, nonnegotiable, automatic penalties; the EPA and state regulators do not have discretion to negotiate or cap the penalties. Because the penalty is issued for each excess ton of emissions, the more severe the non-compliance, the greater the total penalty. Other violations as well as excess emissions may result in supplemental civil and/or criminal penalties. Compliance is also encouraged through the use of incentives, including progressively punitive provisions for missing monitoring data, reduced frequency for monitoring equipment quality assurance checks when superior test results are achieved, and clear consequences for cases of excess emissions.

Banking Benefits

Allowance banking provisions of the Acid Rain Program provided significant benefits in the form of increased flexibility for emission sources and early emission reductions that provided improved air quality. There was significant overcompliance during the modest first phase of the program. Phase I emission sources reduced SO_2 emissions 3 million tons more than required by the cap. These excess reductions clearly provided a substantial amount of environmental and health benefits early in the program. Notably, the large bank of millions of allowances also provided a buffer for the expanded coverage and tightening of the emissions cap under Phase II as well as the new lower cap levels set in CAIR. Concerns about the overuse of the bank in a single year appear to be unfounded. Emission sources in the Acid Rain Program and NO_X Budget Trading Program have not used excessive numbers of banked allowances in any year of the programs' history.

Innovation

The flexibility of the US cap and trade programs and the continuous incentives for emission sources to reduce emissions to either avoid using allowances or free them up for sale have led emission sources to adopt a wide range of compliance techniques and new types of control arrangements which emerged over time (EPA, 2006d; EPA, 2006e). Emission sources complied with the Acid Rain Program by improving operation of existing scrubbers, retrofitting with scrubbers that obtain greater removal efficiency, moving to relatively lower sulfur coals from local coal mines, transporting low-sulfur coals from the Powder River Basin in the Western US, and even importing less polluting coals or coal blends. For the NO_X Budget Trading Program, the power industry installed various advanced post combustion controls to lower NO_X, enhanced the capability of simple inexpensive combustion controls to perform as well as earlier efficiency estimates of advanced controls, and learned to use certain coals with specific combustion controls to reduce NO_X levels.

Certainty

Under a cap and trade program, managers at emission sources must develop long-term compliance and investment strategies to cost-effectively reduce emissions. Effective planning requires certainty about the future level of the cap and the number of allowances the emission source will receive. While no study has been done on how far into the future a cap should be defined, providing emissions sources with certainty ten to 15 years in the future should provide enough certainty for managers to make investment decisions. In addition to information about the level of the cap, an emission source needs to know how many allowances it will receive in the future. Under the Acid Rain Program, EPA issues allowances in perpetuity (i.e., the allowances don't change) and 30 years in advance. If allowance allocations are periodically recalculated, the length of time between recalculations should be long enough to provide the necessary certainty.

Also, if allocations are recalculated, the allocation approach should create incentives for emission sources to reduce emissions by a greater amount than is necessary. For example, recalculating allocations based on historical emissions creates an incentive for an emission source to emit at the maximum permissible level so that they are not penalized in the next allocation calculation for the source's excess emission reductions. Basing the allocation on heat input or output would not create such an incentive.

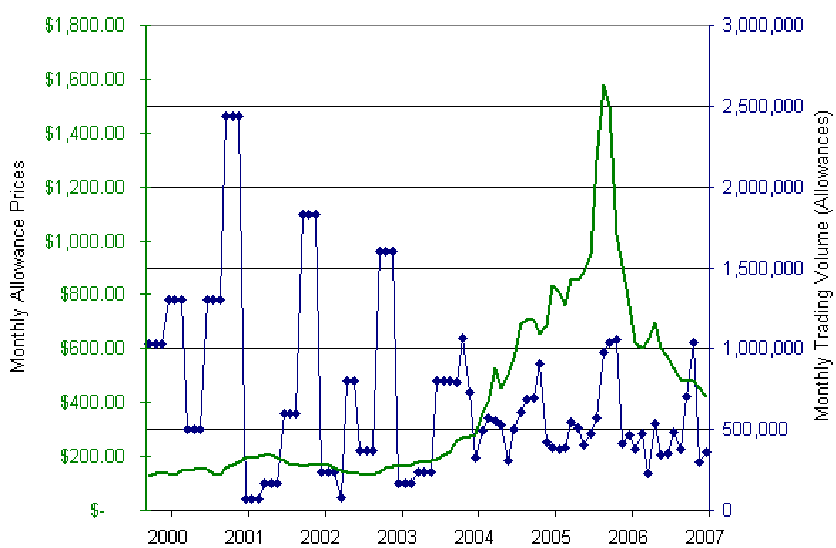
Administrative Efficiency

The use of information technology to manage allowance holdings and transactions and collect, quality assure, and manage emission data, enables EPA to operate the Acid Rain Program and NO_X Budget Trading Program with a very limited number of staff. Approximately 50 full-time staff operate the SO_2 cap and trade program while an additional 20 full-time staff operate the NO_X cap and trade program. Most of these staff are responsible for certifying and auditing monitoring equipment and data and providing compliance support to the regulated community (McLean, 2007). Processing allowance transfers requires minimal EPA staff effort with 98 percent of the transactions done online by market participants.

Price Stability

When establishing cap levels for the US cap and trade programs, EPA analyzed the expected compliance costs for attaining the level of the cap. Generally, EPA's estimates overstated the costs because the models and studies were not able to foresee the adjustments and innovation that occurred during compliance. The US experience has shown that when new programs start, allowance prices are generally higher than expected for some short period of time, but then drop and stay relatively stable. Figure 4.17 provides information about SO_2 allowance prices and market volume in recent years. The one price spike in allowance prices occurred shortly after the announcement of CAIR and is the short-term reaction to the start of a program which relies on the Acid Rain Program bank. Subsequently, CAIR has influenced current SO_2 allowance prices and the entry of new speculative players in the marketplace with a limited understanding of the market (EPA, 2006d).

Figure 4.17: Acid Rain Program Allowance Prices and Trading Volume, 2000-2007



Source: EPA, 2007a

Non-Electric Power Sector Emission Sources

Emissions that contribute to the formation of ground-level ozone are attributable to a wide range of sources. Because electric power plants were responsible for approximately 20 percent of NO_X emissions from stationary sources, EPA included flexibility in the NO_X Budget Trading Program to include large industrial boilers, cement kilns, and/or process boilers. Since the program began in select states in 2003, non-electric power emission sources in the NO_X Budget Trading Program have reduced emissions by approximately 35 percent (Napolitano et al., 2007a), demonstrating that their inclusion provided additional cost-effective emission reductions. EPA has found that, like the electric power sector, industrial sources can manage sophisticated monitoring and reporting systems successfully.

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